ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. 57. No. 15. 220 Broadway, New York, April 11, 1907.

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RAISING A BRIDGE TO ALLOW CLEARANCE FOR A PASSING DREDGE.

The half-tone herewith presented shows two wrecking cranes raising a double-track bridge 54 ft. long on the B. & O. R. R., in order to allow a clearance for a dredge working on the Cedar Creek Drain, near Auburn, Ind. Throughout this branch of the system great inconvenience has been caused by these dredges which are working upon drainage and irrigation canal work and which must pass under railroads at places where the clearance is much too small for them to fully get under the bridges. In this case the wrecking cranes hoisted and held the girders high enough for the dredge to pass underneath them and the track was obstructed only about two hours, one hour of which was taken by the dredge in working on the excavation.

The railway work was under the direction of Mr. L. A. Curtis, Division Engineer, and the dredging done by Mr. J. W. Pearl, to whom we are indebted for the accompanying photograph and information.

STEAM SHOVELS AND STEAM SHOVEL WORK IN RAILWAY CONSTRUCTION.

An important and interesting matter which was assigned last year to the Committee on Roadway of the American Railway Engineering and Maintenance of Way Association was that of investigating and reporting upon the type of steam shovel best adapted for roadway construction. In its report for 1902 the committee dealt with a similar subject, but in regard to railway improvement work. The selection of a shovel for general roadway construction, however, brings up the construction of new lines as well as the improvement of existing lines, and the committee states that it is probable that one class of shovel would not be suitable for all purposes, for the reasons quoted below:

1. In opening up new lines, it is often advisable to have a small light traction shovel to precede the regular work and cast out to the sides material from cuts, so that the loading track grades may be reduced and economically operated.
2. A standard shovel, such as the committee will recommend, would be required, and would be available either on new lines or for improvement work.
3. It frequently occurs that a standard shovel is too heavy for certain soft cuts where it might be advisable to finish with a much lighter class of machine.
4. Many railways are fortunate in possessing large ballast pits, in which it would be advisable to use a shovel much larger than the standard.

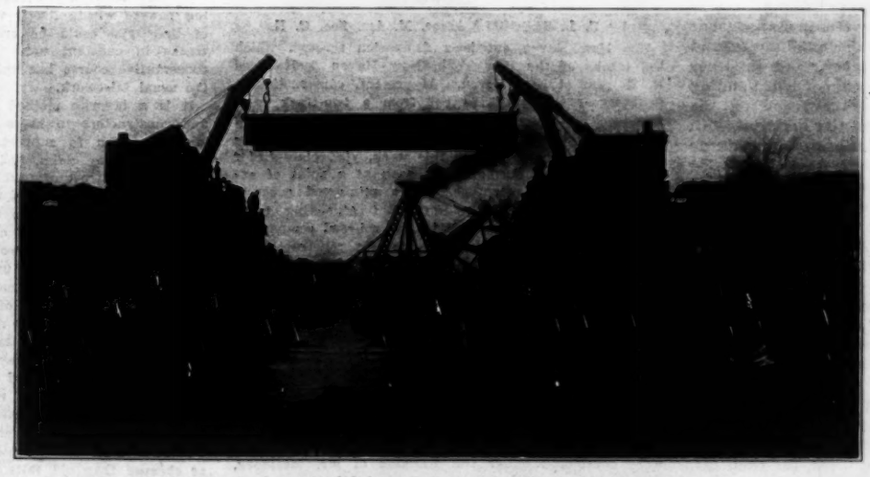
STEAM SHOVELS.—In the selection of machines of this class, however, there are three important points that should be given careful consideration, regardless of the work to which the machine is to be assigned: (1) Care in the selection and inspection and acceptance of all material that enters into the machine; (2) the design in regard to strength; (3) the design in regard to production of work. As the result of the replies received to a circular letter of enquiry the committee in its report made certain recommendations, and some of these we have tabulated below for convenience of reference:

STEAM SHOVEL FOR RAILWAY CONSTRUCTION.

	Suggestions by members.	Recommended by committee.
Weight	25 to 90 tons.	70 tons.
Dipper	1¼ to 5 cu. yds.	2½ cu. yds.
Boiler pressure	100 to 200 lbs.	120 lbs.
Clear height above rail at which dipper unloads	8 to 18 ft.	16 ft.
Depth below rail which dipper will dig	2 to 8 ft.	4 ft.
Movements of dipper per minute from entering bank to entering bank	1 to 6	3
Tank capacity	1,000 to 7,000 gals.	2,000 gals.
Coal bunker capacity	1 to 6 tons.	4 tons.
Jack-arm spread	14 to 28 ft.	18 ft.
No. of pit men	3 to 8	4

As to the use of cable or chain for hoisting, seven replies favored the former and 27 the latter. In spite of this predominance in favor of the chain, the committee recommends the cable hoist on account of the economy in cost of renewals and repairs, and states that this recommendation was made after the subject had been given very careful consideration. It also recommends the use of a cable in swinging the crane, the replies in this case being seven in favor of friction gear and 31 in favor of the cable. In the opinion of the committee, the housing of the men has not been given the attention that it demands, either by manufacturers or users of steam shovels, and although the engineman and fireman are usually well protected, the craneman is entirely unprotected. If he is to be retained as a necessary employee, he should be protected, and the committee recommends that permanent housing be provided for all employees. Of the replies received bearing on this point 26 favored permanent housing and 10 favored temporary protection. The recommendation for the use of four pit men is based upon work under ordinary circumstances. In regard to the recommendations as to the capacity for coal and water given in the table, it is stated that ordinarily a day's supply of coal should be provided, while it is generally possible to supply water at least every 12 hours.

The replies received as to the width of spread of jack-arm showed a great difference of opinion, varying from 14 ft. to 28 ft. The committee recommends 18 ft., and, having in mind that it is often necessary to provide for narrow cutting, it believes that an extra short-arm should be provided for each machine. The committee is also of opinion that it is advisable to have the crane made to swing back beyond the jack-arms, so that cars can be loaded in tunnel or rock-cut work where the entrance is narrow and the cars cannot be pulled beyond the machine. Of the replies 13 favored and 23 opposed this feature. As to the shovel track construction, tee-rails are recommended, and this construction was advocated in 12 replies, while 5 advocated chair rails and 2 advocated rails on stringers. The length of track sections varies from 3½ ft. to 6 ft. The committee recommends the latter, and also recommends strap joints.



A PLACE WHERE NAVIGATION HAS THE RIGHT OF WAY.

CARS.—For the car tracks the recommendation is for standard gage, only two favoring narrow gage as against 32 for standard gage. As to the style of car, the committee recommends a standard car, with permanent sides, swinging hinged doors and aprons between the ends. In the replies received regarding this point a minority of members favored 5-yd., 12-yd., 15-yd. and 30-yd. dump cars, while others favored ordinary railway flat cars; but the majority were in favor of the cars as recommended by the committee. It is recognized, however, that the ordinary flat car must frequently be used, and in such case special care should be taken as to the following matters:

1. See that the car is strong enough for the purpose for which it is to be used.
2. Note that brake-wheels are in good condition; and in case material is to be plowed off, these must be placed at side of car.
3. See that stake pockets are in good condition and not spaced too far apart; 4 ft. apart in the center of the car and closer at the ends of the car is considered good practice.
4. See that the stakes are strong enough to prevent accident or derailment of plow.

DUMPING AND PLOWING MATERIAL FROM CARS.—Where the material is to be dumped from a trestle to form a bank, with a haul of less than two miles, the recommendation is for light cars and light trestles; 15 replies favor this, as against 12 in favor of heavy cars and strong trestles. In the use of an unloading plow hauled by a cable 31 members stated that their experience had been satisfactory, while six have had unsatisfactory experience. Only three recommended the old plan of hauling the plow cable by a locomotive, while 32 recommended the use of an auxiliary engine, the size of drum varying from 3 to 5 ft. diameter. The committee recommends the use of an auxiliary engine, with cylinders 12 × 12 ins. and a 4½-ft. drum, this diameter permitting four wraps of 1⅛-in. cable to be made. The machine should be able to develop a pull of 60 tons, and would weigh about 28 tons. The use of 1⅛-in. cable, 1,200 ft. long, is recommended. The committee recommends that when the raise is light the center plow should be used, but side plows are more advantageous in making heavy fills; the use of a reversible plow is not recommended. The plow should be of strong construction and provided with a trailer; it should be not less than 4½ ft. high and 36 ft. long over all, with a weight of about 7 tons, although the weights given in the replies ranged from 2 to 10 tons.

SPREADER CARS.—The two-arm type of spreader is recommended, handled by compressed air; 26 replies advocated air, as compared with six for the hand windlass and one for steam. Some other features are tabulated below:

SPREADER CARS.

	Suggestions by members.	Recommended by committee.
Spread of wings	5 to 35 ft.	20 ft.
Limiting angle of wings	20 to 80 degs.	45 degs.*
Height above rail for depositing material	4 ins. to 5 ft.	2 ft.
Depth worked below rail	6 ins. to 2 ft.	2 ft.

BUILDING BANKS.—For building embankments with trains on a new location the committee makes recommendations as follows, the figures in parentheses representing the individual opinions submitted to the committee: The vertical limit allowed for raising the track with material dumped should be 4 ft. (2 ft. to 15 ft. suggested), and the same where a central core is put up by teams and widened with material from the steam shovel (2 ft. to 20 ft.); the committee, however, does not recommend this latter method unless material can be borrowed cheaply from the side. For fills of over 4 ft. in height (4 ft. to 75 ft. suggested) a temporary filling trestle should be used under ordinary circumstances, but this naturally depends upon the availability and expense of the necessary timber. As to other methods, three members recommended building a narrow-gage or standard-gage track on the natural surface and unloading the material with side plow or dump cars, jacking up the track as the material is deposited. Four others suggested the availability of contractors' dump wagons and carts, and one advocated the suspension of two cables held at proper spacing to support a dumping track. The committee calls attention to the ordinary graders, cableways, power scrapers, traveling cranes, suspended bridges and other types of mechanical appliances that might be used according to the conditions and the amount of material to be handled. Several such devices have been described in our columns.

In making embankments with trains on an existing line under traffic, it is not wise to use the work trains on the main track where the raise is to exceed 4 ft.; the lifting should be done gradually with not more than 6 ins. for each lift. This method may be economical where sand, gravel or cinders can be used. Where the traffic is heavy and the track is to be raised more than 4 ft., a temporary running track should be built at one side, and the main track jacked up vertically; the length of track affected and the cost of temporary track are taken into consideration, and some members have advocated this method for heights varying from 2 ft. to 20 ft. Where the track is to be raised more than 6 ft. (3 ft. to 30 ft. suggested), it would be economical to throw the main track to one side and build a dumping trestle; in this case, of course, the availability and cost of timber must be considered. Another method suggested was to build a new temporary grade outside of the slope stakes for the new bank. Some members also called attention to the practicability or first widening the embankment to its full width and as much higher as possible without interfering with traffic, then build a new track on this new bank, when the old track can be taken up and bank raised.

SHRINKAGE IN EMBANKMENTS. — The committee recommends allowance for both height and width in new banks, and 20 replies approved of this, while two favored allowance for vertical shrinkage only, and two for horizontal shrinkage only. The allowances suggested and recommended are tabulated below:

	Suggestions by members.	Recommended by committee.
Black dirt, trestle filling	7 to 30%	15%
Black dirt, raising under traffic	4 to 20%	5%
Clay, trestle filling	5 to 30%	10%
Clay, raising under traffic	2 to 20%	5%
Sand, trestle filling	3 to 15%	6%
Sand, raising under traffic	2 to 15%	5%

In conclusion we quote from a letter written by the chairman of the committee (Mr. H. J. Slifer, New York), and embodied in the report:

There appear to be no theoretical rules to decide what amount of allowance should be made for settlement of new embankments. Naturally the question is affected by the character of the foundation under the embankment and the character of the material making the embankment. The ordinary rule to use 10 % for shrinkage in height up to 25 ft., and 15% for banks over 25 ft. in height, looks well in a book, but it would appear foolish to follow such a rule by making a 100-ft. embankment 115 ft. high. If you did so, the chances are that you would have to lower the grade before the track was laid. I believe it a good practice to allow 10% in height with a limit of 5 ft., which I would not exceed except foundation is in a swamp.

It is now conceded that the proper place to provide for shrinkage of embankments is in the width, and here there can be no limit. However, where there is good material and foundations, with very high banks, I would recommend increase of width as follows:

10% for banks less than 25 ft. high.
15% for banks between 25 ft. and 50 ft. high.
20% for banks between 50 ft. and 75 ft. high.
25% for banks between 75 ft. and 100 ft. high.

Possibly the last is too strong, and there should be a limit to increasing width as well as height. Banks will naturally settle, and you want the material on the shoulders so that the track forces may keep the roadway built up to its full height and width.

CONCRETE ARCHES WITH OLD RAIL REINFORCEMENT.*

By C. L. SLOCUM,† Assoc. M. Am. Soc. C. E.

The New Haven cut is a depression through which the tracks of the New York, New Haven & Hartford R. R. pass at New Haven. At present, construction is in progress enlarging the cut from a two-track to a four-track road, and at all intersecting streets new bridges are being erected. Three types of bridge construction are being used on this work, viz., plate-girder spans, a Warren through-truss span at a point of extreme skew and curvature, and a reinforced concrete arch construction, the reinforcement consisting principally of old rails discarded by the railroad company.

By far the largest portion of highway construction is this third type of bridge, consisting of a series of arches, each arch spanning a pair of tracks. This viaduct type of construction was used at Fair and Union St. crossing, where four pairs of tracks are spanned. Similar construction will be used at Crown, Chapel, Court Sts. and Grand Ave. Piers between pairs of tracks had to be used in all these street crossings because this portion of the city and "The Cut" are nearest high water in elevation, and more depth could not be taken for a structure of greater span.

Several studies and methods of flooring these crossings were considered under the direction of Mr. McHenry, Vice-President; all but one were rejected because of the difficulty in affording free and easy egress for the smoke and gases. Any construction similar to or like I-beams and jack-arches that would, in any way, form pockets for the gases, was considered comparatively short-lived and expensive in maintenance. Some form of a smooth arch offered the readiest solution to these requirements. What was finally evolved was a flat three-centered arch which conformed to the best advantage to our double-track clearance diagram. While practically nothing was gained in depth of structure in using this flat arch in preference to the other methods of spanning a pair of tracks, the arch form best facilitated the egress of gases, so that a train, in passing through, practically ventilates or draws out after itself its own smoke and gases.

Essentially this reinforced concrete construction consists of embedding steel elements or units in concrete. The elements or units are of such form and dimensions and so placed in the concrete as will most adequately afford the greatest strength to the given shape. In this bridge work old track material such as abandoned rails, fish-plates, and bolts, railroad scrap in other words, is the given material for reinforcement. Supplement new material, in the shape of rods, bent plates, bolts and lacing, is added to make up the fabricated units and to bind all into a frame and mesh work. Reference to the accompanying drawing showing these various steel units, will indicate how the reinforcement was arranged in the concrete.

REINFORCEMENT.

An arch unit, it will be seen, consists of a rail in its natural position following the extrados of the arch, and within 3 ins. of its surface, bolted at the crown to another rail which is inverted and which follows the curve of the intrados and about 3 ins. from its surface. Where the rails separate, bent plates or lacing is inserted which is bolted to the flanges of the two rails, making a truss frame or unit. In short, all arch units are of this construction. The arch units, it will be seen, are spliced into the pier or abutment units. A pier unit is made up of a vertical rail to which, at fixed heights, are bolted short pieces of rail to which are spliced the rails of the arch unit. Where the arch units are next to an abutment or the end of the bridge they are spliced into the abutment units or anchor frames. The abutment units in shape follow the exterior shape of the abutment. The lacing, of bent plates, of the constituent rails makes the unit or frame. In review and speaking generally, all units are composed of two rails, except the pier unit, which is composed of three pieces, and in shape follow the exterior surfaces of the particular part in which they are embedded.

In this work the main item of cost to be studied is in the work of fabrication of these rail trusses or units, consequently full length rails were used as far as possible.

Theory and practice tell us, convincingly, that the finer the distribution of metal in the concrete the more homogeneous the reinforced concrete; but in the use of these large steel sections other advantages accrue and much is gained in stiffness. When the reinforcement sections are large, shorter and easier methods in erection can be used where falsework of the usual kind cannot be employed. These advantages were considered in the use of large sections. If it is found necessary, these unit frames and reinforcements are of ample strength, size and stiffness to support the arch lagging. Those who have seen the completed reinforcement of Fair St. readily admit that it has considerable sustaining powers within itself, without the concrete. Arches of this type could be erected in perfect safety over tracks in constant use. However, where possible, a conservative course has and will be pursued, employing the usual falsework.

It is a favorite method of some European designers and constructors to make the reinforcement large and strong enough to support the necessary lagging and adjuncts. They claim, and it seems plausible, that the saving in the cost of forms is far greater than the increased cost of the added steel area necessary for self-support. A disadvantage in using such large sections is that the areas are not elastic; in other words, where smaller areas of steel would have sufficed, the large areas had to be used for uniformity of construction.

This unit truss construction is properly continuous along the entire length of the structure, making easy a careful placing of the reinforcement. In the use of large sections, such as the fixed rail section, constant care must be taken to have as few kinds of frames as possible. Each new kind means a new shop template and added cost. Small rods lend themselves to any variety and set of circumstances without much trouble, being readily bent and twisted to suit particular purposes.

In railroad work no material is more readily at hand or cheaper than old rails and fittings, and if the railroad shops could have fabricated this reinforcement as was originally intended, it is extremely doubtful if more economical reinforced concrete could be built with the same large measure of reserved strength in such large sections. Considerable difficulty was experienced in obtaining old material uniform enough to go together easily in the field. There are five different makes of rails in the Fair St. bridge. Much time was lost in adjusting and hammering obstinate fish-plate connections into place.

In physical characteristics the rails varied very much. Before the actual work of the fabrication of the reinforcement commenced, some experiments were conducted to see if the material intended for use could be bent

*Portion of a paper presented before the Connecticut Society of Engineers at the 23d Annual Meeting, Hartford, Conn., Feb. 13, 1907.

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cold to the severest curves required. Unfortunately, the first few rails bent had exceptionally good elastic qualities and were easily bent to the curves of shortest radius without any signs of cracking or fracture of the metal at the bending points. It was concluded that this material could be handled cold at the desired curves. When the actual work of fabrication commenced the rails crystallized and snapped off short under cold bending, and after trying various kinds without success, resort had to be finally made to heating the rails before bending them.

No requirements were attempted in bending the rails to the curves shown on the drawings. The sections being large and cumbersome to handle, 3 ins. leeway from the reinforcement to the surface of the concrete was allowed for difficulties in exact bending. In the erection of the Fair St. reinforcement, the distance of the rail reinforcement to the surface of the concrete varied from 3 to 6 ins., but was never allowed to be any less than 3 ins.

As to the spacing of the reinforcement units, 3 ft. was the prevalent spacing in most of the construction; in places it was slightly less than 3 ft., and sometimes 4 ft. For instance, at Fair St. the alinement is on a 4° curve, consequently the reinforcement units had to be placed in radial lines to avoid an endless variety of units, had it been attempted to run the rail trusses parallel to the center line of the street.

As to whether the reinforcement trusses are spaced 3 ft. or some other distance apart, necessitated some little theory and computation. As an elastic arch with its bending moments far less material is required than is used. The nature of the reinforcement, its arrangement and possible uses, suggested computations on the basis that each arch consisted of two cantilevers carrying a small suspended span in the middle. This method of computing the stresses in the constituent materials was considered the best under the circumstances. For loading, the heaviest concentrations, as steam road rollers and trolley cars, were considered in the design. Whether the span is considered as a composite beam or an arch, the rails in the extrados may be considered as in tension while the rails in the intrados as members in compression. The material for tension members is selected from a promiscuous lot, and splices were made and adjusted accordingly. Where the joints in the compression members or intradosial rails were open and a poor fit could not be helped, Babbitt metal was poured in to insure tightness and a perfect transmission of the forces. In the intrados, splice plates are bolted to the lower flanges of the rails in an endeavor to develop as much of the rail section as possible in tension, in addition to the regular fish-plates and bolts.

Between the rail trusses, following the intrados and extrados, are inserted ½-in. twisted rods spaced about 1 ft. c. to c. longitudinally and 2 ft. c. to c. transversely. The upper and lower points of crossing are tied in by ¼-in. vertical round rods. The entire reinforcement made a compact rigid steel skeleton.

As can be seen from the drawing, the old rail trusses are in convenient shipping and handling sizes.

The crown thickness is 14 ins., 8 ins. being allowed for two depths of rail which varied somewhat with the kinds, plus 3 ins. of concrete covering on each side. Bitulithic paving 3 ins. in thickness is the wearing surface of the roadway. This is laid on the rough top of the solid spandrel arches.

As can be seen from the nature of the construction, 14 ins. crown thickness does not permit the usual caliber of water and gas mains or a great number of telephone conduits. Nothing of this nature could be inserted in the reinforced construction. The only resort left was to insert all the necessary pipes and conduits for present or future use, in as deep a sidewalk as could be made.

The sidewalks are all given a 10-in. gutter depth and sloped back to the coping of the bridge at the rate of ⅝-in to the ft. All pipes and conduits are conveniently laid in the material composing the sidewalks and are in a good measure accessible for repairs.

The cross-section shown specifies the kind of material composing the walks and the arrangement of the pipes and conduits in them. Incidentally, this section also shows the arrangement of the reinforcement through the crown of the arches and through the piers.

A section of a proposed curb is shown, which has been used with some degree of success in several of our large cities. Sometimes an angle is inserted in the corner to prevent chipping. The wearing qualities of this kind of curb seemed doubtful as compared with the usual granite curb, so the latter kind will be used in its place.

The nature of the foundation material at the different bridge sites and the heavy superimposed loads will make necessary in most cases the use of piles in the pier and abutment foundations. The driving of piles is the first operation in preparation for the foundations. They are spaced about 3 ft. c. to c. and figured as being safely worth about 15 tons. The foundations in concrete are then brought up to the lowest elevation of the reinforcement. Then the falsework is commenced. No steel of whatever description is placed until the completion of the falsework.

CENTERING.

In brief, the forms consist of bolted plank trusses of proper curved form spaced some 4 ft. apart carrying 2-in. plank lagging on top. In section and construction this form resembles a large sewer invert. The curved forms are supported on timber bents composed of 12 × 12-in. verticals spaced about 4 ft. apart. Three bents to the span are used, one being placed at the crown, the other two at the ends. These bents are braced in both direction by 2 × 6-in. diagonal strips. The arch trusses consisted of 3 strips of 10 × 12-in. plank in short sections shaped to the curve of the intrados, and two 2 × 10-in. planks in suitable lengths for the straight bottom chord; 2 × 6 in. plank composed the diagonal struts between the chords. The bents carrying the curved forms rested on sills, between which and the bottom timber of the bents were inserted oak adjusting wedges by which the falsework could be adjusted to any desired elevation. Half-inch bolts are used in assembling the different truss members. 20d wire nails are used in nailing down the lagging plank to the arch trusses.

In the building of the Fair St. bridge, this arrangement of falsework has served its purpose adequately. The arch forms were set an inch higher than the figured elevations to provide for any settlement. The forms and supports were so made as to be available for similar arches for the other streets.

ERECTION.

The false work in place, the placing of the rail trusses and units commenced by resting them on small 3-in. blocks on the lagging, allowing the specific distance from the surface of the concrete. Adjusting the rail frames and splicing them is by far the most tedious part of the job. At Fair St. this work proceeded slowly on account of the variety of material. The old fish-plate holes did not occur uniformly and much trouble was encoutered in avoiding the interference of bolt heads. This experience at Fair St. demonstrated the need of more uniform material for the other bridges to properly facilitate the work. The placing of the reinforcement and its detail consumed most of the time in the construction of the Fair St. bridge.

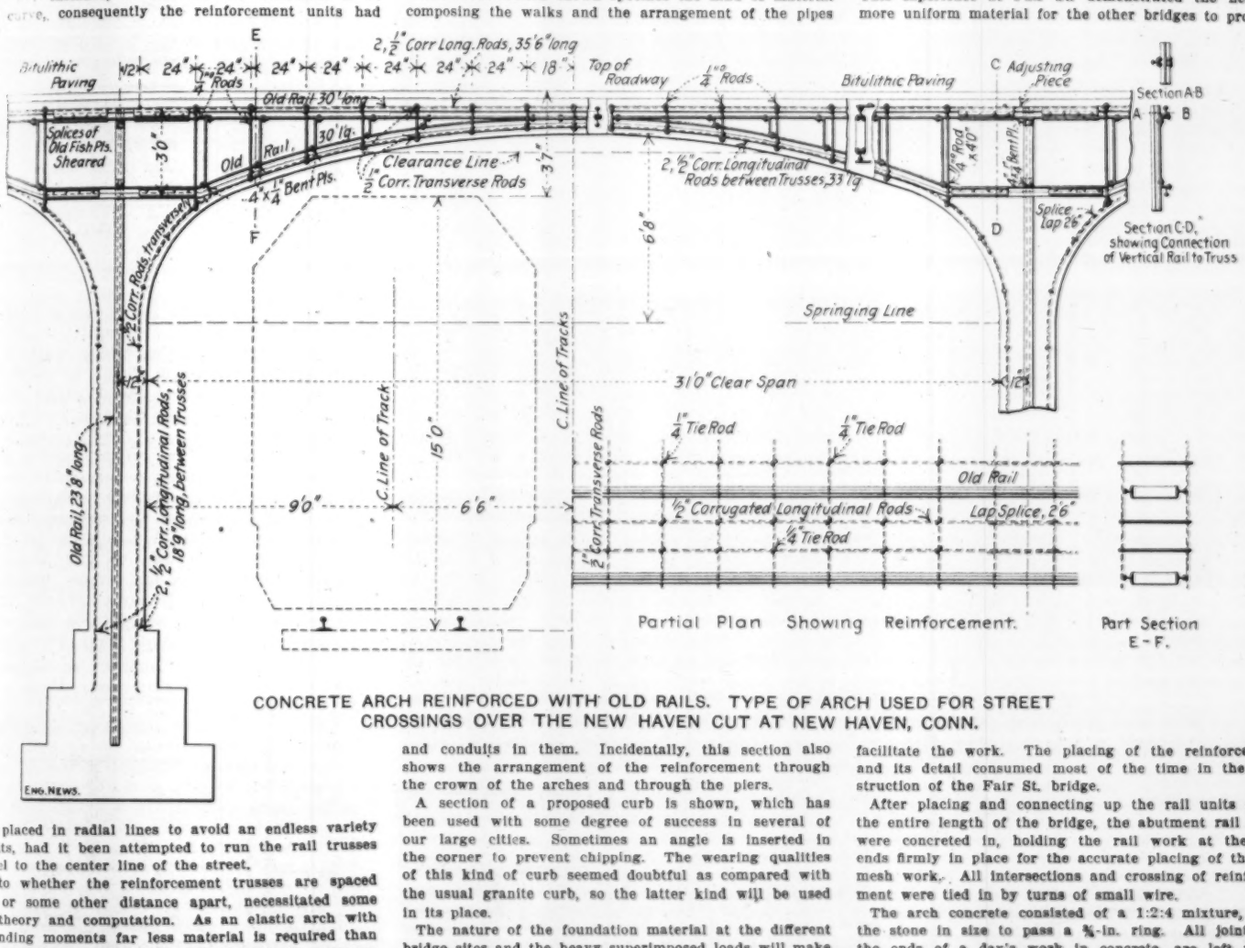
After placing and connecting up the rail units along the entire length of the bridge, the abutment rail units were concreted in, holding the rail work at the two ends firmly in place for the accurate placing of the rod mesh work. All intersections and crossing of reinforcement were tied in by turns of small wire.

The arch concrete consisted of a 1:2:4 mixture, with the stone in size to pass a ¾-in. ring. All joints, or the ends of a day's work in concrete, are left rough and, if necessary, the next day are cleaned and moistened for the best bond.

Exposed side surfaces and other parts where the forms could be easily removed when the concrete was green, were rubbed off smooth by a hand rubbing board with sand and water. Inaccessible parts, such as the exposed intrados of the arches, received an inch layer of cement mortar before the concrete was placed, while the sides of the piers and abutments were spaded. Exterior surfaces at Fair St. have come out satisfactory.

The Fair St. arches and the street surface of the bridge follow a longitudinal parabolic curve. It is about 150 ft. long and 40 ft. wide, with a roadway 26 ft. wide and two sidewalks, each 7 ft. wide. It contains about 1,550 cu. yds. of concrete and 350,000 lbs. of reinforcement. This bridge and the other reinforced concrete bridges will have the standard high board fence, but it is hoped when this portion of the New Haven Railroad system is electrified and the noise, smoke, and dirt are mere recollections, this fence which we will now have to look at with regret, will be replaced by a neat and artistic reinforced concrete balustrade, a fit associate for so comely a bridge.

Messrs. C. W. Blakeslee & Sons, of New Haven, are



CONCRETE ARCH REINFORCED WITH OLD RAILS. TYPE OF ARCH USED FOR STREET CROSSINGS OVER THE NEW HAVEN CUT AT NEW HAVEN, CONN.

the contractors and builders of all the reinforced concrete highway bridges as well as all other masonry, necessary excavation relating thereto, and work in connection with this improvement. The Yale Safe and Iron Co., of this city, are the fabricators of the rail reinforcement. The Aberthaw Construction Co., of Boston, supplied the rod reinforcement. Warren Bros., of Boston, will lay the bitulithic paving.

All the engineering questions were handled by Mr. E. H. McHenry, Vice-President, in charge of Engineering. Mr. Edward Gagel, Chief Engineer, and Mr. W. H. Moore, Engineer of Bridges, under whose supervision this bridge work was designed and is being constructed, are members of this society. The writer is Assistant Engineer in charge of the design of the bridges of the New Haven Improvement.

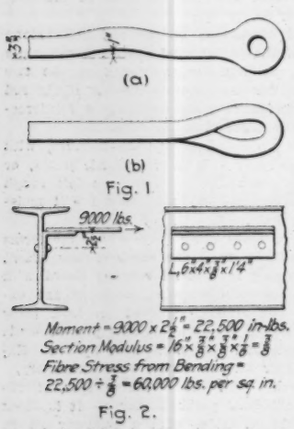
"COMMON PRACTICE" AND COMMON DEFECTS IN STRUCTURAL STEEL WORK.

By EDWARD GODFREY.*

When an engineer criticizes a design of steel work on the ground of faulty details, and makes a stand for good and consistent design throughout, the defense is generally set up that the construction objected to is "common practice," and that other structures having the same glaring faults have "stood the test" and are "giving satisfaction." It is notorious that highway bridges and mill buildings, as commonly built, contain fault after fault that no self-respecting engineer would be willing to defend. Yet the consulting engineer is asked to pass these glaring absurdities for no more potent reasons than the ones above quoted.

What answer is an engineer to give to arguments such as these? Is he to pass features of a design that his judgment and calculations tell him are bad, just because he cannot cite an example where the same detail has been a cause of failure? Are we to wait for calamities and fatalities to happen before making improvements that reason would dictate? Accidents in small bridges and buildings are not chronicled for our perusal. If a severe storm takes away a small bridge, or a large one, it is set down to the severity of the storm and not to the weakness of the bridge. The bridge simply goes as an offering to appease the storm god!

Many years ago a great calamity occurred in England because of insufficient wind bracing in a structure. Royal commissions investigated the pressure of wind, and as a result, the writer believes, it was decreed that structures should be designed for a wind pressure of 55 lbs. per. sq. ft. If a corporation attorney and an expert legislative whitewasher had combined to produce a law to defeat its own purpose, they could not have done better than this, at least if the law is executed as American laws often are.

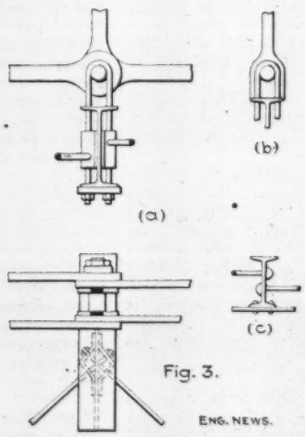

(a)
(b)
9000 lbs.
L 6"x4"x⅜"x14"
Moment = 9000 x 2½" = 22,500 in-lbs.
Section Modulus = 16 x ⅜ x ⅜ x ⅜ x ½ = 7/8
Fibre Stress from Bending =
22,500 ÷ ⅞ = 60,000 lbs. per sq. in.
Fig. 1. Fig. 2.

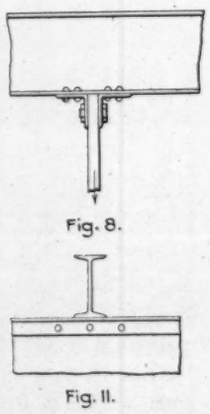
A wind load of 55 lbs. per sq. ft. on the windows of our buildings would leave few of the larger ones whole. The same pressure on frame buildings would destroy many of them. In fact, this pressure exerted on all of the broad surfaces above the ground would bring a great part of them down to the ground.

High wind pressures on small surfaces, like those of truss members, or a chimney stack, are good and proper; but it is unfortunate that any such pressure should be specified on broad surfaces, like the side of a building, for the reason that actual provision for such pressure would result in freak design. Inability to provide against a high wind pressure by practicable means has given rise to a subterfuge in the shape of fanciful assumptions as to certain fractions of the wind being taken by the "inertia of the structure."

Another potent argument used by the defense is this: "If you cannot provide for the wind load specified, what is the use of calculating the wind stresses at all? Use common sense!" Now, common sense is the one human sense that is not common in its working in different individuals of the species. It is quite easily influenced by the interests of the individual. To agree on a plain proposition of pounds is easier than to agree on the elusive matter of common sense.

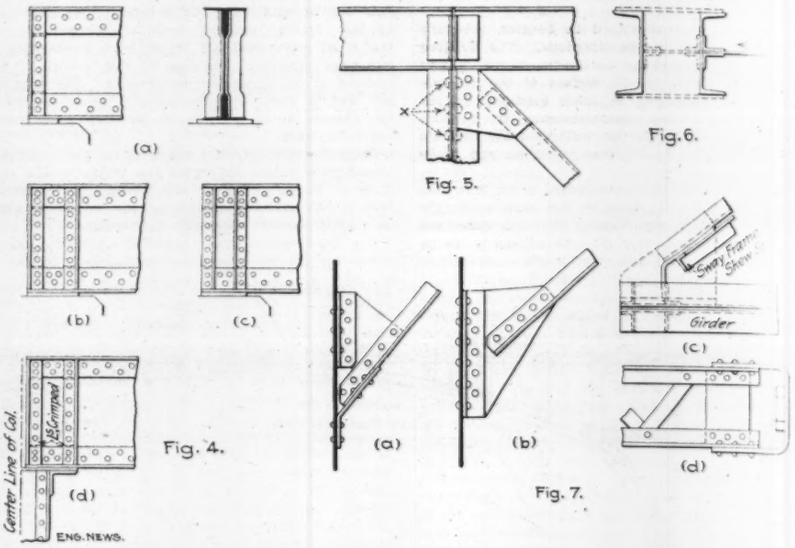
If there is one way above another to bolster up a weak design, it is to brace the structure thoroughly. But, strange to say, the count that can be placed against the greatest number of structures is that they are insufficiently braced. The matter of bracing, however, is not the only one in which common practice is at fault. It is the purpose of this article to point out some of the absurdities reiterated in designs of steel structures to such an extent that they may reasonably be cited as "common practice."





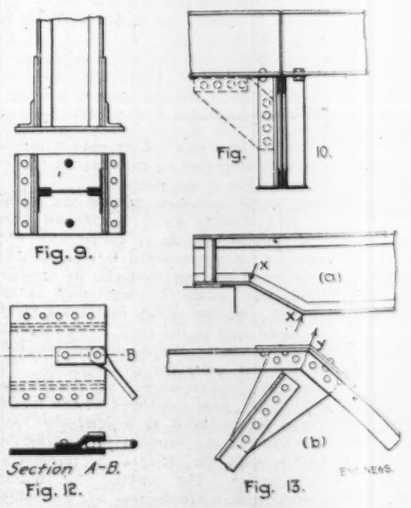
If this were a record of failures, to show that steel work does collapse when poorly designed, an instance could be given of an immense building that collapsed twice during erection on account of insufficient bracing, and another of a girder-span that quietly dropped one of the old locomotives on its line with fatal results, after "giving satisfaction" for a third tury. It is about as instructive to r that a vessel whose calculated capacity was ins. failed to receive and retain a cub liquid.

The load for which a highway bridge is seldom realized, and this is the final argument for the defense: "It will



its load." If you ask, as the writer did, having in view the rights of the purchaser, whether barrels containing 50 gallons should be supplied to fill a specification calling for 63-gallon barrels, you will probably get the reply he got, "Yes, if that were the custom."

The strain-sheet of a bridge usually shows adequate sections of main members, but the details are sometimes insufficient to develop more than a small fraction of the strength of these sections. No doubt the blame of some of this wasteful inconsistency can be laid directly to the draftsman designing the details. The writer has many times found bridge companies willing to correct details, at considerable expense to themselves, when the faults have been pointed out.



The following examples are not imaginary cases, but are actually-observed instances of violations of common principles of mechanics.

Case 1. Some eye-bars of a bridge were bent out of line an inch, as shown in Fig. 1, at (a). This may have been done to shorten bars bored too long. It will be seen by calculation that the extreme fiber stress due to bending alone is double the direct unit stress, making the total unit stress three times that intended. The build-

*Monongahela Bank Bldg., Pittsburg, Pa.

ers maintained that the bars were all right and not overstressed.

Case 2. Some loops were made of flats, as at (b), Fig. 1. This is not a square bar scarf-welded in the ordinary way, but a flat welded on the narrow edge, and the material is steel! On some bridges recently examined all of the flat bars had loops made of a separate piece brought around and welded together and then butt-welded to the bar. The writer was informed that it is the practice in some quarters to make alleged eye-bars in this dangerous fashion.

Case 3. A lateral connection on the side of a floorbeam was made as per sketch in Fig. 2. As seen, besides giving tension on rivets, which might be allowed in a proper detail, the fiber stress in the connection angle is 60,000 lbs. per sq. in. The writer was accused of being guilty of "unnecessary refinement" (!) in objecting to this detail, and was told that it is "common practice."

Case 4. This faulty detail is shown in Fig. 3. Its name is legion, and it has a large family of relatives. The original is shown at (a). Here the laterals of a truss span are attached to the web of a swinging floorbeam, and there is nothing to prevent the floorbeam from swinging if the laterals are stressed. The wooden floor is about all that saves such a structure from sure ruin.

Some genius came along and introduced as a hanger an eye-bar with a straight end square to the axis, as at (b). This offers a trifle of resistance. A bar 2 or 3 ins. wide will support but a small load on an arm of a foot or two. Someone still more cautious continues the hanger down and rivets the floorbeam to it. Thus a built hanger of the healthy proportions of two angles 2½ × 2½ × 5/16-in. may be called upon to take a bending moment in a small span that will give unit-stresses between the elastic limit and the ultimate strength of the steel. In one small highway span the unit-stress from wind alone on four angles 3½ × 2½ × ¼-in. was found to be 20,000 lbs. per sq. in., and in a railroad span the unit-stress on two 12 × 7/16-in. connection plates was found to be 24,000 lbs.; these on "standard" designs, where it might be expected that the chaff was all winnowed out.

The sketch at (c) is a variation on the same thing in which building struts are made of small I-beams. These are uneconomical as struts, when not braced at intermediate points, on account of the small lateral stiffness. The beam struts in this case had no other end connection than the rivets in the bottom flange.

It is hard to see what justification there can be for the survival of this ancient blunder.

Case 5. This concerns crimped stiffeners. It is not denied that a stiffener whose sole office is to stiffen a web-plate can be crimped with perfect safety, and it is contended that a specification requiring such a stiffener to have rivets enough to take all of the shear in the web at the section where it occurs is absurd on its face, since the taking of this shear would necessitate giving it back again, as the stiffeners are not connected to anything but the web. It would mean the stressing of the rivets equally in two direction, or, in other words, the neutralizing of their stress.

The fault with sketch (a), in Fig. 4, is that the pair of crimped stiffeners must act as a column to take the full reaction of the girder. A crimped stiffener is a column already failed by buckling. If a column in place had taken this shape due to heat, it would be declared useless. Compression must travel in straight lines, or, if compelled to change its direction, secondary stresses are the result. The mere fact that the crimping of these angles is a process of local forging that is never followed by annealing to restore uniformity in the steel is enough to condemn crimped stiffeners in compression. Furthermore, it is practically more difficult to make a neat fit against the flange angles on the end of a forged angle than on the end of a straight angle. End stiffeners and others taking concentrated loads should be straight and have fillers under them of the thickness of the flange angles.

The sketch at (a), Fig. 4, is further at fault for reasons given under Case 6.

Case 6. It is a very common thing to see stiffener angles placed as at (b), Fig. 4, with the outstanding legs at the edge of the masonry bearing plate. The outstanding legs of angles supply the greater part of the end bearing, as the other legs must be cut or ground to fit the fillet of the flange angles. With the angles turned as at (c), Fig. 4, a good distribution of the load is effected, whereas with the angles as at (b) this is not the case. Sometimes, moreover, the flange angles run a little short. With stiffeners as at (a), (b) or (d), and the flange angles a little too short, the already inefficient bearing is seriously weakened.

One aggravated case was found where the end stiffeners were crimped, and turned wrong, and were considerably out of line with the column angles, which had to take their load. This is shown at (d), Fig. 4, and occurs in a long viaduct of recent construction.

Case 7. Figure 5 shows a traction brace, or longitudinal diagonal, attached to the angle of a viaduct post. It is clear that this could rip off by pulling the heads off two or three rivets marked x. This would be immensely improved by running the connection plate across the post to take rivets in the other angle also; though it is not thereby rendered an ideal detail, as there is no direct connection between the brace and the viaduct beam which acts as a strut.

Case 8. Figure 6 shows a connection of a knee brace to a post, such as the brace of a portal to the end post of a bridge. Heavy braces are sometimes thus connected to thin webs that would not begin to resist the capacity of the braces. If a diaphragm is added, as shown dotted, the strength is at least doubled. If the end of the brace is forked and connected to the flanges of the channels, the strength is made still greater.

Case 9. Eccentric rivet connections are too numerous to mention. Figure 7 (a) shows one common example. An attempt is made to balance this detail by a bent plate at the toe of the connection, but the result is only a balancing in appearance. A bent plate is not suitable for taking direct stress. In this case, when the brace is in tension, the stress would tend to straighten out the bend. As shown at (b) the detail is balanced.

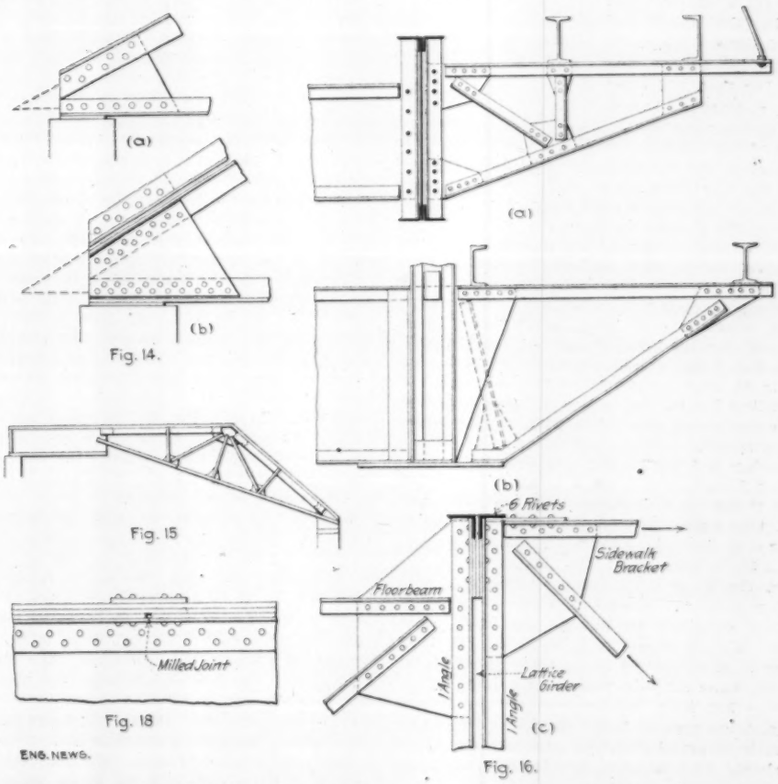


Fig. 14. Fig. 15 Fig. 18 Fig. 16.

Case 10. The detail shown at (c), Fig. 7, showing the end connection of a sway-frame in a skew-span, is another example of the wrong use of a bent plate. This is in the sway-frame of a plate-girder span on a skew. The bent plate is suitable for taking the shear, that is, the vertical component of the stress in the diagonal brace, but the stress as a strut is unprovided for. A horizontal plate, as shown dotted, would take this stress.

Case 11. In the detail at (d), Fig. 7, there is another case of the inefficiency of a bent plate. The U-plate shown is in bending at the corners. If the strut angles were brought up against the U-plate, with a tight fit, the compression would be taken direct into the angles.

Case 12. Tension on rivet heads, as already intimated, is not bad when kept within limits. A tension one-half of the single shear value of the rivet is not too high. The detail should be symmetrical, and the connecting angles should be thick enough to resist the bending. All rivets counted upon should be near the heel of the connecting angle. There should be not less than four rivets in any connection for tension. Rivets are often preferable to bolts in tension, because of (1) the difficulty of making bolts tight, (2) the free use made of common erection-bolts in bolted connection, (3) the fact that rivets seal the metal better than loose-fitting bolts.

In Fig. 8 is shown a detail which was used to support a large section of floor. It was evident that all of the eight rivets were counted upon in tension. The four nearest to the heel of angles would have to take all of the load, as it is impossible for the others to come into action until the first four failed. This is a very poor detail.

Case 13. The anchorage of columns is often made as in Fig. 9. It is often of great advantage in mill building columns to have them anchored for bending so as to aid in resisting wind stresses. Such an anchorage as this one is of scarcely any use in resisting bending. The bolts are in the neutral axis of the column, and they do not take hold of the shaft of the column. They should pass through the bottom connection-angles.

Case 14. In this example, Fig. 10, one stringer is riveted to the top of a floorbeam and the other slides. There is nothing to stiffen the floorbeam and balance it against overturning when one

stringer is loaded with live-load and the other is not. The same criticism holds against a single-webbed column on top of which one beam rests and is riveted, while another slides. The addition of a gusset brace, as shown dotted, helps this detail out by bracing the floorbeam to the fixed stringer.

Case 15. In this case, Fig. 11, a cross-beam not only lacked stiffeners under the flange angles of the girder, but found only one rivet in its neighborhood to take its load.

Case 16. Figure 12 shows a lateral hitch found in many old (and unfortunately in some new) bridges. What the upper bent plate can do to add to the strength of this detail is hard to see. Sometimes there are two rivets in this upper plate, and it is rendered a trifle better; but such a bent plate is by no means capable of resisting any considerable stress. The idea in the minds of some designers seems to be merely to provide something that will offer some resistance before final rupture and tearing apart of the structure occurs. They do not consider the necessity for maintaining the integrity of the detail while taking the legitimate stress of the member. This is exhibited not only in this detail but in many others herein shown.

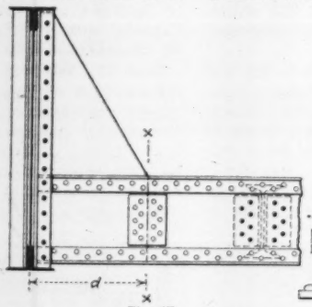


Fig. 17.

Case 17. This concerns angular bends in members under stress, such as flange angles of girders. It is illustrated at (a), Fig. 13. Apart from the possible injury to the metal, due to the forging, there is a force x which bisects the angle between the straight parts. For the part of the flange angle lying against the web this force is at least partially resisted, but for the outstanding leg of angle it is not resisted, and as a consequence the other part of the angle is overstressed.

Assuming a bend of 20° and 6 × ½-in. outstanding flanges, the force x is about one-third of the stress in the angle. At 16,000 lbs. per sq. in. this force x would then be about 16,000 lbs. for each 6 × ½-in. flange. On the two angles, say 6 × 3½ × ½-in., at 16,000 lbs. per sq. in. net section, the force x is about 43,000 lbs. This would require six or seven rivets, and there would be only one or two at the bend. The absolute absurdity of such a design is thus apparent. Sharp curves in members under stress have the same fault in a somewhat less degree. Anything but long, easy curves should not be used, and the curved flange should be thick and as narrow as practicable. If bends are necessary they should be reinforced by plates against the web.

Case 18. This is shown at (b), Fig. 13. It involves a combination of a bent splice plate, which has all of the faults of Case 17, with a faced joint of two members coming together at an angle. The faced joint is just a variation of Case 17, with the added uncertainty of a possible bad fit or an open joint. There are no rivets at the bend to take the force y.

Case 19. This concerns failure to make truss members intersect at common points or at points of application of the load. One very common example is shown at (a), Fig. 14, a sketch of the ends of the chords of a roof truss. These often intersect a foot or two outside of the support. The result is that the chords are compelled to take bending moments for which they are not designed.

It happens in the case of roof trusses that the calculated load is seldom realized, but this does not release the designer from the responsibility of making a consistent design. The case shown at (b), Fig. 14, is a truss supporting water tanks. Here every pound of the stress is there most of the time, and the use of such questionable design, with its possible fatal results, is utterly inexcusable. Enough imperfections will find their way into a structure without introducing gross errors that every structural designer should know are such.

Case 20. The example shown in Fig. 15 belongs by itself. The designer evidently thought that though his chords did not intersect over the support, he had a deep girder to take the bending moment. At the inner end of this girder the bending moment cannot jump into the air, but it must be taken by the chords acting individually in bending.

Case 21. Sidewalk brackets are a prolific source of inconsistencies. Members will be duly proportioned and detailed for their stress up to the point of the main support, and then the stresses are sometimes lost sight of. Figure 16, at (a), ought not to need any comment, but it is a very common style of sidewalk bracket design. It is hard to see how the few rivets in the floorbeam, which are generally only enough to carry properly the vertical load of that member, can be expected to take also the torsion due to the sidewalk load. This is apart from the total inadequacy of the rivets in the vertical stiffeners which are in tension. Another fault in this bracket is the failure of the top and bottom angles of the bracket to meet under the outside stringer. This gives large bending moments in these angles.

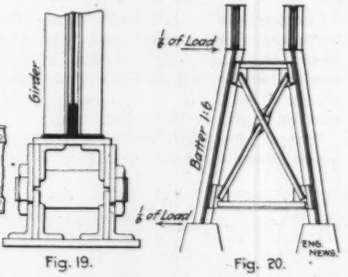


Fig. 19.

Case 22. At (b), Fig. 16, is shown an absurd detail. The total vertical shear of the bottom brace of the sidewalk bracket would have to be taken by the lateral plate. A member as shown dotted would relieve this.

Case 23. At (c), Fig. 16, is an astounding example of the lengths to which confidence in the strength of steel sometimes carries a designer. It is to be hoped that this is the result of ignorance, but it is time that some good, wholesome instruction be given to those who are responsible for such blunders. This is in a new viaduct carrying a wide sidewalk. The apparent strength of the sidewalk bracket for tension in the upper flange is thirteen rivets in shear. It can be seen, however, that *if the heads pulled off four rivets, this bracket would fail.*

Case 24. Figure 17 is a sketch of the floorbeams of a through railroad girder-span. It is manifest that there should be enough rivets in the flange angles connecting to the web to take the full stress in the angles in the distance between the girder and the stringer. It is often overlooked, however, that there should be enough rivets in the space d to take the full flange stress at the section xx. The flange stress at this section is just as definite a quantity as that at the stringer, and is sometimes as much as half of the latter. This is more especially apt to be a weak point in the design of a floorbeam in which the web-plate is counted upon to assist the flange. The plate cannot well be spliced for bending, and the angles must take the full flange-stress.

Case 25. Typical of a large number of cases is the one shown in Fig. 18, a common way of splicing the flange-plate of a girder in the compression flange. A milled joint is depended upon and a perfunctory splice plate is used. In the figure the milled joint is shown open. It is more liable to be open than closed. If it is open the thickness of a sheet of paper, the entire stress is on the remaining parts of the flange and cannot come on the joint. Where only a part of any member is spliced, there should be the full number of rivets and an equivalent area in the splicing parts, in a compression as well as in a tension member.

Fig. 20.

Case 26. In Fig. 19 is shown the end of a heavy girder-span, one requiring a pin support on account of the long span and great weight. Naturally the load to be carried is unusual. It will be seen that the webs of the girder shoe are not only beyond the end stiffener angles of the girder, but also beyond the flange angles. The bending moment on the plate across the bottom of the girder is very great. These webs should be well under the stiffener angles or else a solid cast shoe should be used, giving a bearing directly on the pin.

Case 27. This is shown in Fig. 20. In the inclined posts of a bent having battered posts there is a large force at the top tending to push the caps together, and the same at the bottom, tending to pull the bases apart. In this bent neither of these forces is adequately provided for.

EXPENSES OF THE CHICAGO DRAINAGE CANAL.

The total cost of the Chicago Drainage Canal up to Dec. 31, 1906, or rather the total expenditures of the Chicago Sanitary District from the time of its organization to the above date, aggregated $52,697,495, while the emergency funds and cash in hand amounted to $473,704. The total receipts were $53,171,199, of which $35,688,266 were from taxes collected, and $17,030,000 from bonds. These figures are from the annual report of Mr. I. J. Bryan, Clerk of the Sanitary District. The following is a summary of the statement of expenditures, and it may be noted that the bridge work amounted to about $5,373,953, or a little over 10% of the total:

Total Expenditures of Chicago Sanitary District to Dec. 31, 1906.		
Right of way		$7,206,573
River diversion, construction	$1,000,186	
Bridge construction	142,486	
Main channel, construction	18,546,204	
Bridge construction	1,978,536	
Controlling works, Lockport	331,254	
Bridge construction	7,873	
Joliet project	1,308,251	
Bridge construction	271,351	
Chicago River; dredging, docking, etc.	2,119,995	
Bridge construction	2,817,048	
I. & M. Canal impt. at Bridgeport	77,010	
39th St. Pumping Station	211,605	
Impt. of Kampsville and La Grange dams	20,464	
Raising roadway of Brandon's Bridge	5,891	
		28,838,161
Water power development	$2,721,428	
Bridge construction	156,658	
		2,878,086
Capitalization & maint. of bridges	403,355	
Maintenance of highway bridges	23,463	
Maintenance account	175,979	
		602,797
Interest on bonds and tax warrants		7,801,863
Taxes on land		72,170
Engineering department	$2,190,074	
Water power development	163,683	
Clerical department	185,711	
Law department	1,097,216	
Treasury department	44,459	
Police department	413,128	
General account	932,623	
		5,026,895
City of Chicago		16,361
Land damages		77,835
Marine damages		15,473
Personal injuries account		4,280
Bridgeport pumping works		90,389
Special Commission, Chi. D. Canal		33,076
Telephone line and repairs		12,418
Weir, McKechney & Co.		22,118
Total expenditures		$52,697,495
Emergency funds in hand, amounts due and balance in hands of treasurer		473,704
Grand total, expenditures and amounts in hand		$53,171,199

LOCOMOTIVES OF THE 4-8-0 CLASS for a gage of 3 ft. have been built for the Londonderry & Lough Swilly Ry., of Ireland, by Hudswell, Clarke & Co., of Leeds, England. They have outside cylinders and Walschaert valve gear, the second axle being the main driving axle. The front drivers have blind or flangeless tires, and the engines can pass curves of 600 ft radius. The principal dimensions are as follows:

Driving wheels	2 ft. 9 ins.
Wheelbase, driving	13 ft. 6 ins.
Wheelbase, total engine	21 ft. 7½ ins.
Boiler, diameter	4 ft. 0 ins.
Heating surface, tubes	1003 sq. ft.
Heating surface, total	1105 sq. ft.
Grate area	15 sq. ft.
Cylinders	15 × 22 ins.
Weight on drivers	28 tons
Weight of engine and tender	50 tons
Coal in tender	4 tons
Water in tender	1,500 gallons

EIGHT YEARS' WORK WITH TRICKLING SEWAGE FILTERS AT THE LAWRENCE EXPERIMENT STATION.

By H. W. CLARK.*

Trickling† or sprinkling filters are an outgrowth of studies made during the past twenty years in regard to the bacterial purification of sewage. In the early Lawrence work, after the principles of successful intermittent sand filtration had been thoroughly worked out, various filters of coarse materials were constructed. The changes that occurred in sewage when passed through such filters were carefully noted and subsequently they were recorded in the reports of the station, of sixteen and seventeen years ago.

Filters of Broken Stone.

In June, 1889, eighteen years ago, a filter of gravel stones was put into operation at the Lawrence Experiment Station, the stones used being of such size that they would pass through a screen "having a mesh ⅜-in. sq., but not through a screen having a mesh ⅛-in. sq."‡ On the same date, another filter was constructed of coarse gravel, the stones being of such size that none "were less than ¾-in. in diameter nor more than 1¼ in."§ Good nitrification occurred in these filters. In summarizing the results, Mr. Mills stated "that the purification of sewage by nitrification and the removal of bacteria is not to any essential degree mechanical but a chemical change." Also that "the experiments with gravel stones give us the best illustration of the essential character of intermittent filtration of sewage—the slow movement of the liquid in films over the surface of the stones with air in contact."

In 1892, fifteen years ago, two gravel stone filters were placed in operation in such a way that air was drawn down through the filters, and the rate of these filters, which were continued in operation until 1898, was at times as high as 500,000 gals. per acre daily. In 1895, two additional filters were constructed, one of gravel stone of the same grade as that used in the construction of the filters just mentioned, and one of good-sized pieces of coke. These two filters were also aerated by forced draft, the air being blown up through them. The average rate of filtration of each was 608,000 gals. per acre daily, and the rate for several months of their operation was 1,000,000 gals. per acre daily. In each of the four filters mentioned good nitrification occurred and the amount of artificial aeration was reduced from time to time until it approximated only about two hours out of each twenty-four. The non-putrescible character of the effluents was noted and discussed in the report of the Board for 1895, page 469. In May, 1899, a filter was constructed of 10½ ft., in depth, of broken stone (see page 448, Report for 1899). Sewage was applied at a rate of 2,000,000 gals. per acre daily and the filter was not artificially aerated. It was operated for seven months, only, but during that period produced a highly nitrified effluent with little odor and containing considerable free oxygen. In November, 1899, Filters Nos. 135 and 136 were constructed and put into operation. At the time of writing these filters have been in operation seven years and four months. At first they were 18 ft. in depth, but they were soon reduced to 10½ ft. in depth (broken stone). They have received sewage at average rates of more than 1,500,000 gals. per acre daily. At times in past years, the rates have approximated 3,000,000 gals. per acre daily and, at the time of writing, Filter No. 136 is being operated at a rate of 4,000,000 gals. per acre daily. These filters, also, as in the case of all the filters subsequently mentioned in this article, have always been operated in the trickling or sprinkling manner and have not been artificially aerated. From time to time other filters operated in this manner have been started, 14 in all to date, and at the present time 7 such filters are being operated at Lawrence. In all this work at Lawrence, the adaptability of different filtering materials for use in the construction of such filters, the effect of different depths of filter and of different rates of filtration, have been carefully studied. In addition, the quality of the effluents produced, judging by the usual analytical standards and by incubation or putrescibility tests, the character of the sediment in the effluents, as compared with the sediment in sewage, and the degree and rapidity of clogging of the filtering material by the storage of retained matters, have all been given due attention. The length of the period of operation now attained by several of these filters makes the Lawrence data upon the last point especially valuable. Eight broken stone filters have been operated as shown by Table I.

It will be seen from Table I. that at the present time certain of the Lawrence trickling filters are in their eighth year of operation, namely, Filters 135 and 136. Filters 117 and 134 were constructed of stone, practically all of which would pass through a sieve with two meshes to the linear inch and little or none through a sieve with a ¼-in. mesh. Filters 135 and 136, 247 and 248 are constructed throughout their entire depth of stone, all of which will pass through a screen with one mesh to the linear inch, 40% through a screen with a ½-in. mesh and about 4% through a screen with a ¼-in. mesh. The stone in Filter 247 contains a slight percentage more of fine material than that in the remaining three filters, and this slight difference has apparently had some influence in causing clogging in Filter 247, as will be discussed later. The stone in these filters, owing to the long narrow shaped pieces into which it breaks, appears to be somewhat coarser than these figures indicate. Filter 222, over Akron pipe and field stone underdrains, has about 7 ft. in depth of broken stone ranging from 1½ ins. to 3 ins. in diameter. Filter 196, operated for only nine months, was constructed of 5 ft. 4 ins. in depth of stone as follows: At the bottom, 1 ft. of field stone 6 to 8 ins. in diameter; above this, a layer 1 ft. in depth of similar stone, 4 to 6 ins. in diameter; then 1 ft. of stone 2 to 4 ins. in diameter; 1 ft. 9 ins. of stone ½ to 2 ins. in diameter; 3 ins. of stone none of which was over ½-in. in diameter; and over the surface 4 ins. in depth of a mixture of buckwheat coal and small pieces of coke.

It will be seen from these statements that the size of material used in these stone filters has varied considerably in different filters and that the depth of filter studied has varied from 5 to 18 ft.

RATES OF FILTRATION AND SEWAGE APPLIED.

The rates at which these different filters have been operated have varied from 1,000,000 to 4,000,000 gals. per acre daily. The averages (Table I.) show practically the true rates of operation of Filters 117, 134 and 196 for their entire period of operation. Filters 135, 136, 247 248 and 222, however, have been operated at times at much higher rates than the averages indicate. Filter 135, for instance, was operated at a rate of 2,500,000 gals. per acre daily during 1903. For the past two years the average rate of Filter 136 has been slightly more than 2,000,000 gals. per acre daily, and at the present time, as before stated, it is 4,000,000 gals. per acre daily. Filters 117 and 196 received regular station sewage, so called; Filters 247 and 248, regular station sewage until October, 1906, since when they have received the supernatant sewage after a period of sedimentation of station sewage. Filter 135 received station sewage during 1899, 1900, 1904, 1905 and 1906 until October; during 1901, 1902 and 1903 sewage that had been passed through a coal strainer was applied to this filter, and since 1906, supernatant sewage from station sewage after a period of sedimentation. To Filter 136, septic sewage was applied during 1900, 1901, 1902 and 1903, but during 1904, 1905 and 1906, until October, regular station sewage. Since October, 1906, supernatant sewage from allowing regular station sewage a period of sedimentation has been applied. Filter 222 has always received Andover sewage that has passed through the settling tank at the Andover filtration area—a strong, ill-smelling, almost septic sewage.

TABLE I.—NUMBER, DEPTH, RATE AND PERIOD OF OPERATION OF SPRINKLING FILTERS OF BROKEN STONE, LAWRENCE EXPERIMENT STATION.

Number of filter.	Depth of filter, ft.	Average rate, gals. per acre, daily.	Length of period of operation.
117	10.5	2,000,000	7 mos.
134	5	1,180,000	2 yrs. 2 mos.
135*	10.5	1,531,000	7 yrs. 4 mos.
136*	10.5	1,658,000	7 yrs. 4 mos.
196	6	1,143,000	9 mos.
222*	8	1,500,000	3 yrs. 8 mos.
247*	5	1,170,000	3 yrs.
248*	8	1,210,000	3 yrs.

*Still in operation.

QUALITY OF EFFLUENTS OBTAINED.

Each and all of these filters have produced effluents containing nitrates. The nitrates in Filters 135 and 136 have averaged over 2 parts per 100,000 parts for their entire period of operation, and have been greater during the past year, 1906, than in previous years, or 4.36 and 3.65 parts per 100,000, respectively. This degree of nitrification has been obtained with Filter 135, operating at a rate of 1,500,000 gals., and with Filter 136, at a rate of 2,000,000 gals. per acre daily. The nitrates in the effluent of Filter 248, 8 ft. in depth, have averaged 1.71 parts per 100,000, and in the effluent of Filter 247, 5 ft. in depth, .60 parts per 100,000. These filters have been operated at average rates of 1,210,000 and 1,170,000 gals. per acre daily. Filter 196, constructed of 5 ft. 4 ins. in depth of the coarse material described previously, and operated at a rate of 1,143,000 gals. per acre daily, produced an effluent containing .61 parts per 100,000 of nitrates, and Filter 222, also constructed of coarse stone, and operating at a rate of 1,500,000 gals. per acre daily, has produced an effluent containing an average of .54 parts nitrates per 100,000.

Throughout all this work incubation tests have been made to show the stability or non-stability of the effluents. The effluent of each filter has contained a large percentage of the organic matter in suspension that was present in the applied sewage, but with this organic matter freed from most of its easily putrescible bodies. For example: the effluents of Filters 135 and 136 have contained 37 and 48%, respectively, of the organic matter in the applied sewage, determined as albuminoid ammonia; the effluent of Filter 247, 55%.; the effluent of Filter 248, 82%, and the effluent of Filter 222, 64%.

Owing to the oxidizing condition existing in these filters, this residual matter has been stable, when the rate of operation of the filter has been properly adjusted to its depth, to the quality of the filtering material and the strength of the sewage applied. The effluents of Filters 117 and 134 were almost invariably non-putrescible, or, in other words, stable. Filter 196, 6 ft. in depth, constructed of the graded coarse material previously described, and operated at a rate of more than 1,000,000 gals. per acre daily, produced an effluent that putrefied at least 75% of the time. At least 98% of the samples of effluent collected from Filters 135, 136 and 248 have been non-putrescible, and about 75% of the samples from Filter 247—constructed of the same grade of material as the filters just mentioned, but 3 ft. less in depth than Filter 248 and not quite half as deep as Filters 135 and 136, have also been non-putrescible. At least 98% of the samples of effluent of Filter 222 have been non-putrescible, notwithstanding the high organic content of the effluent and the coarseness of the material of which the filter is constructed. It has been noticeable that a stable effluent has been often produced by this filter, even when nitrates were not present in the effluent.

During 1906, samples of the effluent of all trickling filters in operation during that year were incubated as usual. Duplicate samples were taken of each effluent after the removal of much of the matters in suspension by three hours' sedimentation; and also samples of the

*Chemist of the State Board of Health of Massachusetts, Boston, Mass., and in charge of the Lawrence Experiment Station.

†Also commonly known as percolating filters, which term has been used for several years by this Journal and is quite generally employed in England.—Ed.)

‡See page 563, Special Report of Massachusetts State Board of Health upon Purification of Sewage and Water, 1890.

§See page 549, same report.

entire effluent (effluent containing sediment), mixed with equal volumes of tap water (the drinking water of the city of Lawrence). None of these samples, with the exception of 22% of those from Filter 247, only 5 ft. in depth, putrefied with five days' incubation, and 82% of the samples from No. 247 that putrefied did so even after the suspended matters were removed, and 30% when mixed with equal volumes of tap water.

Many investigations and experiments on the keeping qualities of trickling filter effluents and on the changes occurring when such effluents are mixed with sewage or water and on their behavior under various conditions have been made. One such characteristic experiment was as follows: Duplicate samples of the effluents of Filters 135 and 247 and of a good tap water were each mixed with 5, 10, 25 and 50% by volume of sewage, respectively, and incubated. At the end of a week, all mixtures of the effluent of Filter 247 had become darker in color and those containing 25 and 50% of sewage were black on account of the formation of sulphides; the mixture of the highly nitrified effluent of Filter 135 with sewage remained unchanged in appearance, but that containing 50% by volume of sewage had developed a fairly strong sour odor; all of the mixtures of water and sewage had, at the end of this period, a strong and decided sewage odor, and that containing 50% by volume of sewage had begun to blacken. The explanation of the better quality of the mixture of effluent of Filter 135 and sewage than of tap water and sewage is, of course, that the effluent contained high nitrates in addition to its free dissolved oxygen, and the oxygen of the nitrates was available for keeping or purifying purposes.

Average analyses of the sewage applied to and the effluents of Filters 135, 136, 196, 222, 247 and 248 are given in Table II.

TABLE II.—AVERAGE ANALYSES OF APPLIED SEWAGE AND OF SPRINKLING FILTER EFFLUENTS, LAWRENCE EXPERIMENT STATION.

(Parts per 100,000.)

Year.	Ammonia. Free.	Albumin'd. nitrogen. Total.	Albumin'd. nitrogen. In solution.	Kjeldahl nitrogen. Total.	Kjeldahl nitrogen. In solution.	Chlorine.	Oxygen consumed.	
SEWAGE APPLIED TO FILTER 135.								
1900	4.09	.62	.27	1.27	.55	9.02	4.31	Regular sewage
1901	6.41	.35	.29	0.72	.59	9.70	2.08	Strained sewage
1902	5.31	.36	.25	0.74	.51	8.50	2.12	" "
1903	4.05	.39	.24	0.80	.49	9.96	2.90	" "
1904	5.15	.95	.47	1.83	.87	12.31	4.86	Regular sewage
1905	2.98	.47	.25	0.92	.47	8.94	3.35	" "
1906	4.54	.67	.38	1.18	.63	12.99	4.57	" "
Av.	4.65	.54	.31	1.07	.59	10.20	3.46	
SEWAGE APPLIED TO FILTER 136.								
1900	4.67	.33	.22	0.68	.45	9.74	2.45	Septic sewage
1901	5.98	.39	.29	0.80	.59	8.73	2.58	" "
1902	4.52	.43	.27	0.88	.55	11.25	2.85	" "
1903	3.80	.35	.22	0.72	.45	9.91	2.93	" "
1904	5.15	.95	.47	1.83	.87	12.31	4.86	Regular sewage
1905	2.94	.43	.25	0.82	.47	9.23	3.26	" "
1906	4.46	.64	.37	1.19	.66	13.03	4.60	" "
Av.	4.50	.50	.30	0.99	.58	10.60	3.36	

CHARACTER OF SEDIMENT IN EFFLUENTS.

Many examinations of the sediment in the effluents have been made and described in the various reports of the past six years. Tables III. and IV. illustrate the difference between this sediment and that of untreated sewage.

STORAGE OF MATTER IN FILTERS.

Up to the present time, none of these filters, with the exception of No. 247, has given trouble from stored matters, either organic or mineral. Filters 135 and 136 have stored practically only 2.5% of the organic matter in the sewage applied and are as open and pass sewage as freely now as when put into operation. Filter 247 has clogged so badly that the filtering material had to be removed and cleaned, this being due partly, as before stated, to the somewhat finer stone in this filter and partly to clogging by fatty matters, owing to experiments upon the disposal of such matters added to the applied sewage. Examination of the filtering materials for the determination of stored matter have given the results shown by Table V. The table shows that at the time of examination Filters Nos. 135 and 136 had stored within them slightly more than ¼-lb. of solid matter per cu. ft. of filtering material; Filter No. 248 only ¼-lb., while Filter No. 247 had stored 2¼-lbs. per cu. ft. of filter. Of this stored matter, from 50 to 60% was organic, from 3.5 to 4.8% nitrogen, from 22.5 to 28.5% carbon, and from 3.8 to 5.8% fat or fatty matter.

SURFACE CLOGGING.

Twice during the operation of these ters, surface clogging has occurred, once in ilter 136, on account of an enormous growt of small worms in the upper few inches of t filtering material, and once in Filter 222, by e growth of an amdorphous jelly-like mass bacteria. Filter 135 was put out of operation or a few days and the worms largely died. They undoubtedly could have been elimin ed more quickly by the use of a germicide, s h as copper sulphate, and this salt was appli to Filter 222, at the time of clogging, in t sewage passed to the filter, and the growth s quickly killed and disappeared, the filter co inuing in good operation.

METHOD OF APPLICATION OF SEWAGE.

Upon these experimental filters, arying in area from 1/2000 to 1/20 of an acre, e sewage has generally been passed by the use of automatic tipping basins, as the object of operating most of these filters was not to study the best method of applying sewage to large filters of a similar kind, but to study the results that could be obtained with such filters receiving properly distributed sewage. During the past year, however, methods of application by sprinkling nozzles, dash plates, etc., have been investigated, but cannot well be described fully here.

To Filter 222 (1/200-acre) the sewage is passed at the present time and has been for eight or ten months, in the following manner: At one side

TABLE III.—ANALYSES OF SEDIMENTS FROM SEWAGE AND EFFLUENTS OF FILTERS 135 AND 136.

	Sewage sediment.	Sediment of filter. No. 135.	No. 136.
Per cent. of total nitrogen (Kjeldahl)	2.37	1.37	1.41
Per cent. of nitrogen determined as albuminoid ammonia	1.30	0.70	0.78
Per cent. that albuminoid ammonia is of total nitrogen (Kjeldahl)	55.00	51.00	55.30
Albuminoid ammonia, parts per 100,000	1,575.00	851.00	952.00
Loss on ignition, per cent. by weight	58.50	27.60	31.50

TABLE IV.—EXPERIMENTS WITH WATER AND SEDIMENTS.

(River Water Saturated with Oxygen; .2 gram of Sediment and 4,000 c. c. of Water in Each Case.)

	Dissolved oxygen at end of five days; per cent. saturation.
River water at end of five days	90.0
Filter 135 sediment and river water	100.0
Filter 136 sediment and river water	70.0
Sewage sediment	1.5

TABLE V.—POUNDS OF MATTER STORED PER CUBIC FOOT OF FILTERING MATERIAL, AND ANALYSES THEREOF, FILTERS 135, 136, 247 AND 248.

(Per cent. by weight.)

Filters.	Lbs. per cubic ft.	Ammonia. Free.	Albuminoid	Kjeldahl nitrogen.	Carbon.	Hydrogen.	Loss on ignition.	Fats.	Albuminoid nitrogen.
135	0.53	.20	2.04	4.00	28.47	3.79	55.0	4.05	1.67
136	0.54	.23	2.17	4.76	31.24	3.91	60.2	3.82	1.78
247	2.28	.01	1.45	3.76	22.49	3.71	50.7	5.78	....
248	0.25	...	2.20	3.51*	.....	....	51.8	....	....

*Including free ammonia.

TABLE VI.—MAXIMUM AND MINIMUM TEMPERATURES, IN DEGREES FAHRENHEIT, AT THE LAWRENCE EXPERIMENT STATION.

(Day Ending at 8 a. m.)

Day of month.	Dec., 1906. Max.	Dec., 1906. Min.	Jan., 1907. Max.	Jan., 1907. Min.	Feb., 1907. Max.	Feb., 1907. Min.
1	45	7	47	32	42	19
2	26	9	41	21	42	23
3	32	0	51	21	24	9
4	17	3	53	29	20	5
5	33	15	42	24	13	3
6	46	28	42	26	20	7
7	31	—5	53	28	24	—3
8	13	11	37	31	27	—3
9	17	10	40	4	27	3
10	34	17	34	5	35	20
11	26	4	42	20	29	—3
12	23	6	38	16	13	—4
13	34	21	35	19	36	0
14	31	21	34	20	49	25
15	45	29	38	2	33	19
16	38	25	13	—10	29	24
17	35	17	14	—5	38	12
18	23	0	30	13	28	8
19	25	2	46	45	33	11
20	35	13	53	20	39	21
21	37	27	23	8	36	4
22	38	23	29	0	15	—13
23	24	11	10	—11	..	..
24	22	12	7	—10	35	—4
25	21	17	14	5	33	0
26	30	12	22	—6	20	5
27	42	23	22	0	31	3
28	39	22	26	—1	31	3
29	44	30	28	2	..	..
30	..	..	31	—5	..	..
31	36	34	22	1	..	..

YEARLY AVERAGE ANALYSES OF THE EFFLUENTS OF FILTERS 135 AND 136.

FILTER 135.

(Parts per 100,000.)

Year.	Quantity applied, gallons per acre dy. for 6 days in a week.	Appearance. Turbidity.	Appearance. Color.	Ammonia. Free.	Albuminoid. Total.	Albuminoid. In solution.	Kjeldahl nitrogen.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen consumed.
*1899-1900	899,900	...	1.12	3.4353	.1606	.1049	.2897	7.64	0.23	.0045	1.42
†1900	1,804,900	...	0.64	2.5212	.2080	.1448	.3752	10.54	0.45	.0131	1.33
1901	1,406,900	...	0.81	3.1645	.2228	.1353	.4019	9.44	2.40	.0132	1.57
1902	1,817,400	...	0.52	1.7452	.1392	.0856	.2510	8.61	2.76	.0071	1.08
1903	2,398,600	...	0.67	1.6000	.1473	.0933	.2858	9.02	1.47	.0107	1.37
1904	1,150,400	8.0	0.57	0.7047	.2889	.1143	.5212	11.17	2.95	.0064	2.30
1905	1,304,000	4.5	0.86	0.7173	.2158	.1059	.3563	8.08	3.47	.0054	1.69
1906	1,469,100	4.7	0.50	0.4437	.2335	.1422	.4128	12.60	4.36	.0061	2.03
Av.	1,531,400	5.7	0.71	1.7915	.2020	.1158	.3592	9.64	2.26	.0083	1.59

FILTER 136.

Year.	Quantity applied, gallons per acre dy. for 6 days in a week.	Appearance. Turbidity.	Appearance. Color.	Ammonia. Free.	Albuminoid. Total.	Albuminoid. In solution.	Kjeldahl nitrogen.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen consumed.
*1899-1900	747,600	...	0.58	3.4273	.1646	.1066	.2969	7.58	0.16	.0170	1.20
†1900	1,004,700	...	0.58	2.2230	.1245	.1131	.2246	10.41	2.20	.0179	1.09
1901	1,402,700	...	0.82	3.4153	.2331	.1344	.4204	8.62	2.00	.0086	1.67
1902	1,806,100	...	0.60	2.3553	.1930	.1050	.3483	9.06	2.66	.0091	1.36
1903	2,257,800	...	0.66	1.6565	.2161	.1027	.3898	9.88	1.91	.0089	1.84
1904	1,938,000	10.5	0.68	1.3883	.3343	.1509	.6030	11.06	2.05	.0096	2.39
1905	2,082,000	6.4	1.14	1.2855	.2911	.1256	.5161	8.29	2.19	.0102	2.26
1906	2,099,200	7.5	0.58	0.8316	.3481	.1952	.6452	12.73	3.65	.0094	2.83
Av.	1,667,600	8.1	0.70	2.0728	.2381	.1292	.4305	9.70	2.10	.0113	1.83

*Nov. 28-April 15. †April 16-Dec. 31.

AVERAGE ANALYSES OF SEWAGE APPLIED TO FILTERS 247, 248 AND 222 DURING THEIR ENTIRE PERIOD OF OPERATION.

FILTER 247.

(Parts per 100,000.)

Temperature deg. F.	Ammonia. Free.	Albumin'd. nitrogen. Total.	Albumin'd. nitrogen. In solution.	Kjeldahl nitrogen. Total.	Kjeldahl nitrogen. In solution.	Chlorine.	Oxygen consumed.	Bacteria per c. c.
58	4.12	.70	.39	1.30	.69	11.04	4.21	1,566,655
FILTER 248.								
58	4.11	.69	.39	1.32	.69	10.97	4.25	1,566,655
FILTER 222.								
54	3.67	.60	.38	....	...	5.72	3.03	1,618,825

AVERAGE ANALYSES OF THE EFFLUENTS OF FILTERS 196, 247, 248 AND 222 DURING THEIR ENTIRE PERIOD OF OPERATION.

FILTER 196.

(Parts per 100,000.)

Quantity applied, gals. per acre dy. for 6 days in a week.	Temp., deg. F. Sewage.	Temp., deg. F. Effluent.	Appearance. Turbidity.	Appearance. Color.	Ammonia. Free.	Albuminoid. Total.	Albuminoid. In solution.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen consumed.	Bacteria per c. c.
1,142,900	61	59	....	.69	2.4760	.2926	.1170	9.52	0.61	.0202	2.06	245300
FILTER 247.												
1,149,833	56	62	10.2	.79	2.5790	.3859	.2236	11.08	0.62	.0205	2.56	334533
FILTER 248.												
1,188,466	56	57	10.2	.73	2.6677	.5677	.2428	10.44	1.77	.0356	3.35	245600
FILTER 222.												
1,446,933	51	52	2.7	.63	2.7640	.3857	.2148	6.08	0.53	.0624	1.93	778666

of the filter is an automatic flush tank into which a stream of sewage runs continuously. When filled the tank is emptied by a siphon into a grid of distributing pipes placed over the filter. These pipes contain orifices ½-in. in diameter. The top of the flush tank is 41 ins. and its bottom is 8 ins. above these outlets. One inch below each outlet and 12 ins. above the surface of the filter are dash plates on supports. These dash plates are 2 ins. in diameter and have their edges turned up at an angle of 45°, making a slight rim ¼-in. wide. As the sewage strikes the dash plates, it is thrown (see Figs. 1 and 2) in a thin umbrella-shaped sheet and breaks into a spray covering an area about 5 ft. in diameter. As the tank empties and the head becomes less, the circle becomes more and more contracted until finally the whole circle has received sewage. The flush tank in use is of such size that when the filter is operating at the rate of 2,000,000 gals. per acre daily it empties once every 9 minutes, 2 minutes being required for the tank to empty. With this apparatus, about 90% of the filter surface is well sprinkled.

TRICKLING FILTERS IN WINTER.

During the winter of 1906-7, Filter 222 received sewage by the method just described at a rate of 2,000,000 gals. per acre daily. The winter has been very cold in New England, and at the Lawrence Experiment Station, about two miles from the Andover filtration area, at which this filter is located, the temperature has been as given in Table V. Records from the locality of the filter show a somewhat lower average temperature.

During this period, from 55 to 60 ins. in depth of snow fell, and of this total depth, about 50 ins. fell between Jan. 12 and Feb. 24, snow falling on 17 days during this period. During nearly all this period, however, the distributing apparatus worked as well and as successfully as during warm summer weather. At times, however, during the winter, one or more of the seven outlets became clogged with floating matter in the sewage and froze, but this clogging occurs in warm weather occasionally; at such times the outlets or orifices have to be cleaned. Occasionally, also, clogging occurs in the supply pipe, etc., and the filter may remain out of operation for a number of hours. During the coldest weather all outlets worked satisfactorily and freezing did not occur unless the orifices first became somewhat clogged. The greatest trouble on this account was from Feb. 3 to 13, inclusive. While snow at times accumulated on portions of the filter and the area upon which sewage was distributed became lessened, still a considerable circle around each outlet was kept free by the sewage, as shown by the accompanying reproduction of a photograph, and the filter remained in good operation. Records of December, January and February are given in Table VII.

Filters of Clinker and Broken Brick.

Besides the stone filters already described, considerable experimental work has been done with filters of clinker and broken brick, these materials being selected, especially the former, as representative of waste materials that might be utilized for the construction of sprinkling filters, and which are utilized in England. One filter of broken brick has been operated and four of clinker. The broken brick filter, known as No. 189, was constructed of 10 ft. in depth of pieces of broken brick about 2 ins. in diameter, was put into operation in May, 1902, and continued until May, 1904, or a period of two years. Raw untreated sewage was applied to it at an average rate of 2,100,000 gals. per acre daily. Good nitrification occurred in this filter, the average nitrates in its effluent averaging over 1 part per 100,000, but its effluent was putrescible fully 80% of the time. (See Table VIII. for analyses.)

The four clinker filters were known as Nos. 233, 234, 235 and 236. Filters Nos. 233 and 234 were constructed of pieces of clinker varying in diameter from ¾ to 1¾ ins., while Filters Nos. 235 and 236 were constructed of pieces varying from ¼ to ¾-in. in diameter. Filters Nos. 233 and 235 were 5 ft. 9 ins. in depth, while Filters Nos. 234 and 236 were 3 ft. 10 ins. in depth. These filters were first put into operation on Jan. 1, 1904. Filters Nos. 234 and 236 were continued for 13 months only, while Filters Nos. 233 and 235 are still in operation. Regular untreated station sewage was applied to Nos. 234 and 236 during their entire period of operation, and to Nos. 233 and 235 until late in 1906, since when

Fig. 1. View of Sewage Sprinkling Filter No. 222, Andover, Mass., Jan. 28, 1907.

settled sewage (regular sewage subjected to a period of sedimentation) has been applied.

The average rate of operation of these filters has been a little less than 1,000,000 gals. per acre daily. All of them have produced well-nitrified effluents, the best nitrification occurring, as would be expected, in the filters of the finer material. At least 95% of the samples of effluent of Nos. 233 and 235 have been non-putrescible and about 80% of the samples of Nos. 234 and 236. Filter No. 233 has stored within it about .4-lb. of matter per 1 cu. ft. of filtering material, while Filter No. 235, of finer material, has stored three times as much matter, or 1.2 lbs. per 1 cu. ft. of filtering material. (See Table VIII. for analyses.)

Conclusions.

When the writer first began to operate the filters described in this article, he called them intermittent-continuous filters, and if named according to the manner of filtration rather than the method of application of sewage, that early name was entirely reasonable, as sewage is passing through them continuously, but so intermingled with air, owing to filter construction and rate of application, that the aerobic conditions prevailing in intermittent filters are always maintained within these filters. "Slow movement of the liquid in films over the surface of the stones with air in contact is the essential characteristic of intermittent filtration of sewage," as Mr. Mills said nearly twenty years ago. The main difference between sprinkling filters and intermittent sand filters is that owing to the size of the open spaces between the particles of filtering material in the sprinkling filters, much greater rates can be maintained and still allow the free entrance of air.

Sprinkling filters are not a substitute for sand filters, which remove practically all the matter in suspension in sewage, but are simply devices for the quick oxidation of the putrefying matters in sewage while allowing the larger body of stable or slowly decomposing matters to pass along with the effluent.

The results given in this article show that with filters 10 or 11 ft. deep, constructed of sufficiently fine material, and operated with such sewage as is used at Lawrence, rates of at least 2,500,000 gals. per acre daily can be maintained and result in good nitrification and in the production of an almost invariably non-putrescible effluent, but an effluent containing much of the residual organic matter in suspension that is strained out by sand filters. In some places such an effluent could undoubtedly be allowed to flow away without further treatment, but such an effluent, owing to local conditions, would often need further treatment, such as sedimentation or sand or mechanical filtration. With lesser depths of filter, the rates must be materially decreased if as good results are desired, as is shown by Filter No. 247. In order to obtain non-putrescible effluents at high rates of filtration, fairly good nitrification is generally necessary, judging from the Lawrence results, and a filtering material not coarser than that of Filter No. 222 should be used.

It is possible when sewage has received preliminary treatment, as by sedimentation or septic tanks, to increase this rate materially. At present, Filter No. 136, operating at a rate of 4,000,000 gals. per acre daily and receiving a strong sewage, but one with much of the matter in suspension first removed by sedimentation, is giving a well-nitrified and generally non-putrescible effluent. Filters of material of as large a size as that of Filters Nos. 189 and 196 failed to produce non-putrescible effluents when receiving untreated sewage at the rates described, although considerable nitrification was accomplished by them. If they had received sewage such as is now being applied to Filter No. 136, much better results would undoubtedly have been obtained, but it is, of course, a fact that the larger the pieces of filtering material the quicker the passage of sewage through the filter, other things being equal—hence the less efficient the purification. These filters of coarse material (Nos. 189 and 196) allowed not only the liquid to flow through quickly but also allowed a too ready passage of the matters in suspension in the applied sewage, and because of this, the sediment in the effluent much more closely resembled sewage sludge than the residual matter appearing as sediment in the effluents of the more efficient filters. Filters Nos. 135 and 136, when receiving untreated sewage at rates equal to that of Filter No. 189, produced effluents stable 98% of the time.

Through such material as was used in the construction of Filters Nos. 135 and 136, sewage will pass at the rate of about 2½ ft. per hour when a rate of 1,000,000 gals. per acre daily is maintained, and this rate of progress can be tripled in deep filters without materially decreasing the efficiency of purification. This follows with deep filters only, however, and is so because the degree of purification obtained by sprinkling filters increases rapidly as the depth of filtering material increases, whatever the rate of operation. With broken stone filters, not over 5 ft. in depth, as Filter No. 247, doubling the rate practically decreases the efficiency of purification one-half. Through filters of material

TABLE VII.—CARETAKER'S NOTES ON OPERATION OF SPRINKLING FILTER NO. 222, WINTER OF 1906-7.

		Applied sewage.	Effluent.
Average temperature, Deg. F., Dec., 1906.		46	44
Average temperature, Deg. F., Jan., 1907.		42	41
Average temperature, Deg. F., Feb., 1907.		40	38
1906.			
Dec. 29.	Settling tank emptied. Filter stopped three hours. The remainder of day filter ran as usual, but registering device had become clogged with sludge.		
1907.			
Jan. 7.	4 p. m., to Jan. 9, 4 p. m., sewage running at same rate as usual, but supply pipe was partly clogged and siphon did not work properly.		
Jan. 18.	Settling tank emptied. Filter stopped 5¼ hrs.		
Feb. 1.	Settling tank emptied. Filter stopped 2½ hrs.		
Feb. 3.	3 outlets stopped.		
Feb. 4.	1 outlet stopped.		
Feb. 5.	1 outlet stopped.		
Feb. 6.	1 outlet stopped.		
Feb. 7.	1 outlet stopped.		
Feb. 9.	1 outlet stopped.		
Feb. 12.	1 outlet stopped.		
Feb. 13.	3 outlets stopped.		
Feb. 22.	Settling tank emptied. Filter closed 2½ hrs.		

TABLE VIII.—AVERAGE ANALYSES OF THE EFFLUENTS OF FILTERS NOS. 189, 233, 234, 235 AND 236 DURING THEIR PERIOD OF OPERATION.

(Parts per 100,000.)

Quantity applied. Gals. per acre daily for 6 days in a week.	Color.	—Ammonia.— Albuminoid. Free.	Total.	In solution.	Chlorine.	Nitrogen as Nitrates.	Nitrites.	Oxygen Consumed.
FILTER NO. 189 (BROKEN BRICK.)								
2,098,700	.90	2.5438	.4163	.1631	9.44	1.18	.0329	2.54
FILTER NO. 233 (CLINKER.)								
963,900	.77	1.9564	.3361	.1603	10.21	1.50	.0316	2.36
FILTER NO. 234.								
949,000	.88	3.4225	.4707	.2431	10.16	0.73	.0768	2.80
FILTER NO. 235 (CLINKER.)								
964,400	.67	1.5201	.2916	.1264	10.64	2.05	.0378	2.20
FILTER NO. 236 (CLINKER.)								
908,900	.77	3.5721	.4411	.2254	11.18	0.50	.0127	2.48

such as that in Filters Nos. 189 and 196, sewage moves about 6 ft. per hr. when such filters are operated at the rate of 1,000,000 gals. per acre daily. Of course, a portion of the sewage travels faster than the main body of sewage, as pointed out by Mr. Mills in his studies of sand filters twenty years ago. Through clinker filters sewage travels more slowly, rate for rate of surface application, owing to the roughness of the material, and the fact that owing to this roughness greater surface area is presented than with equal-sized pieces of broken stone. This causes such filters to be more efficient, depth for depth, than filters of stone. Through clinker filters constructed of clinker having diameters approximating the stone in Filters Nos. 135, 136, etc., sewage progresses at a rate somewhat more than one-half the rate in the stone filters, when the rates of application to the filter surface are equal. This advantage, then, is with the clinker, but the obvious disadvantages are the ultimate breaking down of this material and the fact that only a limited quantity is available in given localities, while stone can almost invariably be obtained. The indications are, moreover, that retention of applied matter and clogging are more to be feared with clinker than with broken stone filters. The degree of nitrification obtained increases rapidly as the depth of the filter increases. Rate for rate, other things being equal, filters 10 ft. in depth will produce effluents containing at least four times as high nitrates as filters 5 ft. in depth, or, in other words, doubling the depth of material increases the degree of nitrification four-fold. This has been continually demonstrated by the Lawrence filters. An increase of 50% in depth will with some filter materials increase nitrification at least three-fold. Judging by non-putrescibility tests, filter efficiency does not increase so strikingly with increased depths of filter material, but, nevertheless, increases rapidly.

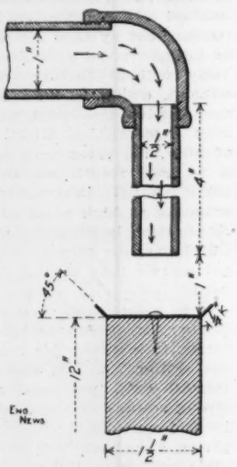


Fig. 2.
Sewage Sprinkler, Experimental Filter, Andover, Mass.

As to methods of application of sewage, the writer believes that the device in use at the Andover experimental filter of the Board (Fig. 2) is simpler than sprinkling nozzles and that the flusk tank and siphon method of operation causes more even distribution than can otherwise be obtained. The dash plates could, of course, if thought desirable, be attached to the distribution pipes and be suspended below the orifices instead of being placed upon the small posts.

Judging from the results of the past winter, it is feasible to operate such filters, even in localities where the winter temperature is similar to that of eastern Massachusetts. A filter of considerable area would need constant attention in winter in order to keep all its distributing devices working, but these devices require much attention in summer, as shown by the operation of large English plants.

THE TUNNELS UNDER THE SEINE FOR THE METROPOLITAN RAILWAY AT PARIS.

By R. BONNIN.*

The Metropolitan Railway of Paris, which connects the Porte de Clignancourt with the Porte d'Orléans, crosses under the two arms of the Seine between the stations of Chatelêt and Place St. Michel by means of compressed-air caissons submerged underneath the bed of the river. Engineering News, in its issue of Feb. 15, 1906, has described these caissons, together with the method of sinking them. It is our intention in this article to complete this description and to give some notes on certain additional very interesting work which was not described in the preceding article, this latter work having taken place after the publication of the article.

As shown in Fig. 1, the larger arm of the Seine is crossed by means of three submerged caissons of nearly the same length (118, 125.9 and 141.7 ft. respectively) and the smaller arm by means of two caissons having each a length of 65.9 ft. These caissons were all sunk with a distance of 4.92 ft. between their ends, which space was afterwards filled by means of an "enveloping caisson," connecting adjacent caissons and forming one continuous tunnel from bank to bank. It is this "enveloping caisson" with which this article principally deals.

Before describing the processes employed to obtain the junction of these caissons, some preliminary observations are necessary. As it was impossible to sink the first caissons following the designed line in an absolutely rigorous manner it was necessary to take account of the differences in alinement produced during the operation of sinking the caissons under the river. The subaqueous tunnels were therefore given a width somewhat larger than the ordinary subterranean tunnels to which they connect (23.94 ft. instead of 23.29 ft.). In reality, during the sinking of the caissons, the difference in alinement never exceeded 0.53 ft., which kept within the excess of 0.65 ft. allowed.

The extremities *a* and *b* (Fig. 1), *c* and *d* and *e* and *f* which face each other between caissons 1 and 2, 2 and 3 and 4 and 5, respectively, were closed, as shown in Fig. 2, by means of temporary plate diaphragms, filled with concrete. These diaphragms were built square across to the level of the top of the tunnel invert, of a size large enough to sustain a concrete wall, in plan 3.94 long and with a width of 1.50 ft., the total width of the submerged caisson.

Under the larger arm of the Seine, Caisson No. 1 is provided, on the shore side, with a recess

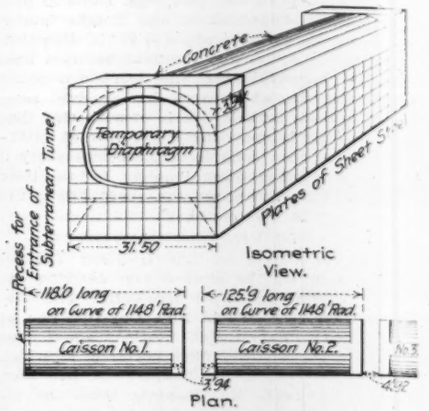


Fig. 2. Diagrammatic Elevation and Isometric View of Tunnel Caissons of Tunnels Under the Seine at Paris.

fitted with a temporary bulkhead, into which the shield of the subterranean tunnel fits. This temporary bulkhead is removed after the shield work is carried into the recess. Caisson No. 3 is connected with the vertical elliptical shaft at the Station de la Cité by a similar device. This same method is also used at all other junctions of the tunnel with stations except that in the other cases the work is not obstructed by the river, and is therefore made much easier. Under the smaller arm of the Seine, Cassion No. 4 is provided on the side of the city with a similar recess into which the shield at Section N joins. Then Caisson No. 5 is connected to the subterranean tunnel which adjoins it and which is constructed by a freezing process not described in this article.

We will now return to the three joints under the river between Caissons 1 and 2, 2 and 3, and 4 and 5. At each joint two caissons have been sunk separated by a bank of earth 4.92 ft. long between the two diaphragms. Through this bank the tunnel section has to be bored. On each side

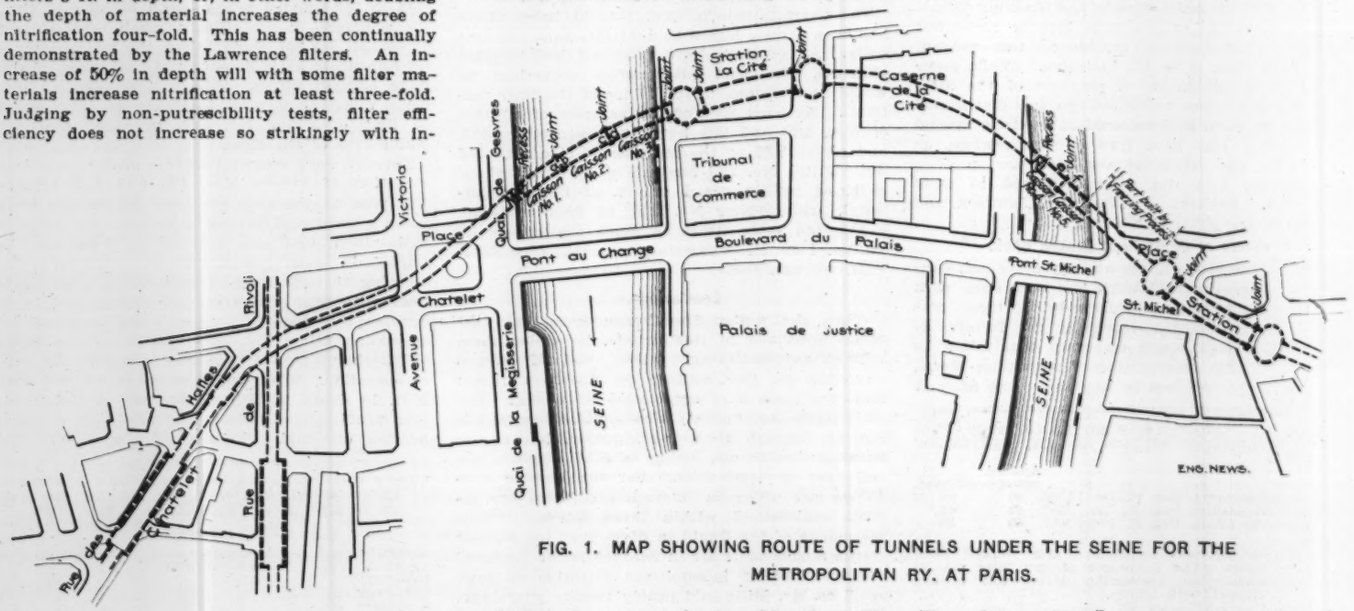


FIG. 1. MAP SHOWING ROUTE OF TUNNELS UNDER THE SEINE FOR THE METROPOLITAN RY. AT PARIS.

*61 Rue Louis Blanc, Paris.

of the caissons at this point a temporary caisson (Fig. 4), 13.12 ft. long, 5.74 ft. wide and 9.8 ft. high is sunk. Of the height 6.23 ft. is reserved for a working chamber, the roof of which is formed by very heavy iron beams connected by an iron plate work placed underneath the beams on account of the direction of the pressure. Each temporary caisson is furnished with a single outlet shaft serving at the same time for workmen and material. The upper work of the caisson shaft is made up of rectangular iron boxes, strongly braced against water pressure by tie-rods and diagonals. In lowering, these boxes are filled with water as they descend, or if this is insufficient weight, with stone.

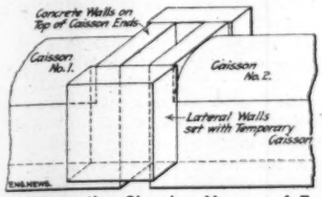


Fig. 3. Perspective Showing Manner of Enclosing Space Between Tunnel Caissons in Tunnels Under the Seine at Paris.

The temporary caissons are lowered by means of compressed air until the level of the ceiling of the working chamber of the large caissons is reached, that is to say, to 42.21 ft. below mean water. The depth of the water at this point being about 16.4 ft. In general, they have but a space of 25.81 ft. to traverse in earth. The two lateral temporary caissons, having reached the depth which we indicate on the left-hand side of Fig. 4, are lifted progressively by means of a windlass, leaving underneath them a mass of masonry of the same dimensions, which has been constructed under the working chamber as the caisson is raised, and which is leveled up to the same level as the concrete walls before mentioned, which surmount the end partitions of the caissons in Fig. 3. It is estimated that 50 tons of initial effort is necessary for the raising of each caisson. The central core is now completely isolated by four walls formed by these two lateral masses of masonry and by the two partitions at the ends of the large caissons. This leaves, about 1.97 ft. below the bed of the Seine, a surface which after being leveled up is ready to receive the open cofferdam next described.

This cofferdam (Figs. 6 and 7) is 36.08 ft. long and 9.84 ft. wide and is built entirely of iron. Its total height is 6.90 ft., of which 5.90 ft. is reserved for a working chamber and 1 ft. for the ceiling, which is made of beams spaced about 1.8 ft. c. to c. and supported at their ends by brackets. Owing to the nature of the pressure on it, the sheet-iron forming the roof is placed on top of the beams instead of underneath, as in the previous caissons mentioned. Two shafts are carried from the working chamber to the surface and the work below is carried on in the open air carried through these shafts. Around its entire lower perimeter the cofferdam is provided with a projection of 0.66 ft. in which is placed either clay or rubber. The cofferdam is heavy enough in itself to resist the buoyant effort of the water, and so rests securely on the four walls while the clay or rubber joint makes the dam entirely watertight.

When the water in the cofferdam has been pumped out it is a simple matter to excavate the core wall and connect up to the tunnel already inside the submerged caissons. These latter are allowed to remain full of water up to this point in the procedure in order to render them more stable and to save effort in pumping them. The excavation is made in hardpan, so there is no danger of the water coming up through the bottom. The entire 4.92 ft. is covered with a monolithic concrete reaching back into the diaphragm ends of the caisson tunnels, thus making one continuous line of work.

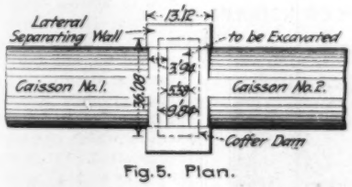


Fig.5. Plan.

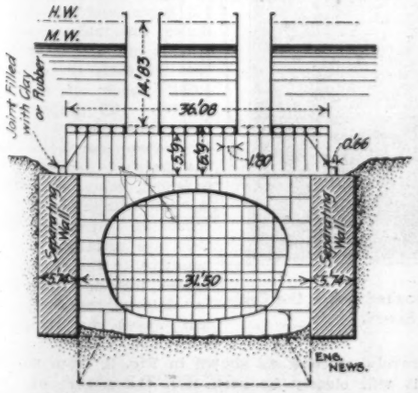


Fig.6. Transverse Section.

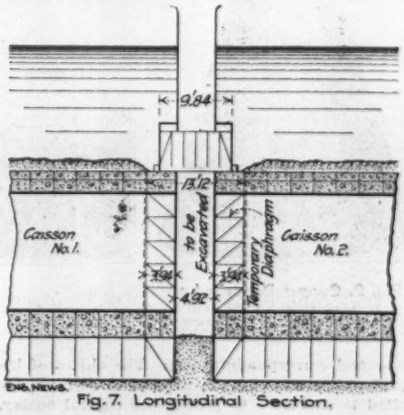


Fig.7. Longitudinal Section.

FIGS. 5, 6, 7. COFFERDAM SUPERIMPOSED OVER JOINTS BETWEEN CAISSONS IN TUNNELS FOR THE METROPOLITAN RY. UNDER THE SEINE AT PARIS.

THE ECONOMICAL UTILIZATION OF LABOR.*

By HENRY L. GANTT,† M. Am. Soc. M. E.

Any scheme of management to be permanently successful must be beneficial alike to employed and employee. Neither those labor unions that regard their interests as essentially antagonistic to that of employers, nor those employers' associations whose only effort is to oppose force by force, can ever effect a permanent solution of the problem of the proper relations between employers and employees.

Those who have given even superficial study to the subject of labor are beginning to realize the enormous gain that can be made in the efficiency of workmen if they are properly directed and provided with proper appliances. Few, however, have realized another fact of equal importance, namely, that to maintain permanently this increase of efficiency the workman must be allowed a portion of the benefit derived from it.

In but few cases has any definite attempt been made to study in a scientific manner the most efficient way of utilizing human labor. Of how much work of various kinds the ordinary man has done, we have many records, but of how much a man especially suited to any class of work can do, we have almost no knowledge. Enough study has been spent on the subject, however, to determine that men especially suited to any particular kind of labor, if supplied with proper implements and intelligently directed can do on an average at least three times as much as the average workman does if the limiting factor is physical exertion; and, if assured proper compensation they will do so day after day.

EQUITABLE COMPENSATION OF LABOR.

It is coming to be realized in the industrial world regarding the arrangements between employers and employees that no arrangement is permanent that is not beneficial to both. The employer who insists on more service than he pays for and the employee who demands excessive wages for his work both lose in the long run.

In other words, unless efficient work goes with high wages the result is apt to be disastrous to both employer and employees. If we would have satisfactory workmen we must learn how to make their labor efficient, for it is to efficient labor only that high wages can be uniformly paid.

Wherever any attempt is made to do work economically the compensation of the workman is based more or less accurately on the efficiency of his labor. Very fair success in doing this has been accomplished in day work by keeping an exact record of the work done each day by every man and by fixing his compensation accordingly. This method, however, falls very far short of the highest efficiency, for very few workmen know the best way of doing a piece of work, and almost none have the ability to investigate different methods and select the best. It often happens then that a man working as hard as he can falls very far short of what can be done on account of employing inferior methods, inferior tools, or both.

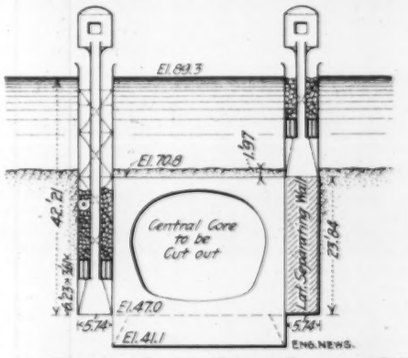


Fig. 4. Transverse Section Through Temporary Side Caissons in Tunnel Work Under the Seine.

In order to get the best results the following conditions are necessary:

First. Complete and exact knowledge of the best way of doing the work, proper appliances and materials.

Second. An instructor competent and willing to teach the workman how to make use of this information.

Third. Wages for efficient work high enough to make a competent man feel that they are worth striving for.

Fourth. A distinct loss in wages in case a certain degree of efficiency is not maintained.

These four conditions for efficient work were first enunciated by Mr. Fred. W. Taylor, and when they are understood their truth seems almost axiomatic. They are worthy of a very careful consideration.

These conditions are really the steps that must be taken to get any piece of work done efficiently:

1st. Learn how to do it right, and how long it should take.

2d. Teach a workman to do it in the manner and time set.

3d. Award the workman greater compensation for doing it in the manner and time set than he can ordinarily earn in any other manner.

4th. Make the conditions of pay such that if he fails to do the work either in the manner or time set he gets only his day's pay.

It is perfectly well known that nearly every operation can be, and in actual work is, performed in a number of different ways; and it is self-evident that all of these ways are not equally efficient. As a rule, some of the methods employed are so obviously inefficient that they may be discarded at once, but it is often a problem of considerable difficulty to find out the very best method. It is only by a scientific investigation that we can hope to approximate the best solution of any problem.

To analyze every job and make out instructions as to how to perform each of the elementary operations requires a great deal of knowledge, much of which is very difficult to acquire; but the results obtained by this method of working are so great that the expenditure to acquire the knowledge is comparatively insignificant.

It would not be possible for me to give you much idea from this platform as to how to do this work, because it is necessary to go into the smallest details of each problem and study them with a stop watch. I can, however, tell you of some of the results that have been accomplished.

In the first column in the following table is given the time needed in the machine shop of the Bethlehem Steel Co. to rough turn work before any study had been made; in the second column is the time it took after the proper study had been made and the conditions adjusted to meet the results of the study. In the third column is given the ratios of work done per hour. The average of these is 3.7.

4-in.	U. S. Navy	tubes.....	21.56	5.4	4.
4 "	" "	jackets	35.15	7.1	5.
6 "	" "	tubes	34.75	8.25	4.
6 "	" "	"	35.00	8.00	4.4
12 "	" "	"	54.50	21.50	2.5
12 "	" "	jackets	123.70	43.83	2.8

*Extracts from an address delivered at the Stevens Institute of Technology.

†Consulting Engineer, 63 Summit St., Pawtucket, R. I.

All the labor of handling pig iron, coal, coke, ore and open hearth melting stock in the yard of the Bethlehem Steel Co. was studied in the same manner and the amount done per man on piece work after the study averaged 3.2 times as much as was done before.

In the Sayles' Bleacheries where I am now at work, I find similar ratios. This means that whether the labor is that of a Pennsylvania Dutch workman in a machine shop, a Hungarian laborer handling stock in the yard of a steel works, or a skilled cloth handler in a bleachery, the amount of work the average workman does under the ordinary conditions is only about one-third of what can be done by a proper workman under the best conditions. I could give other illustrations of this ratio, which seems to be pretty uniform.

In other words, when a man sets his own task, as he virtually does in ordinary day work, he usually does about one-third of what a good man fitted for the work can do under the best conditions.

INSTRUCTIONS.

As a result of our first step or our scientific investigation, we in general find that it is possible to do about three times as much as is being done; the next problem is how to get it done. First, I wish to say that no matter how thoroughly convinced we may be of the proper method of doing a piece of work and of the time it should take, we cannot make a man do it unless he is convinced that in the long run it will be to his advantage. In other words, we must go about the work in such a manner that the workman will have confidence in us and feel that the compensation offered will be permanent.

When we have established this condition of affairs we are ready to start a workman on the task, which, when properly set after an investigation, is such as can be done only by a skilled workman working at his best normal speed.

The average workman will seldom be able at first to do more than two-thirds of the task, and as a rule not more than one of five will be able to perform the task at first. By constant effort, however, the best workmen soon become efficient, and even the slower ones often learn to perform tasks which for months seemed entirely beyond them.

COMPENSATION OF LABOR.

Buying labor is one of the most important operations in modern manufacturing, yet it is one that is given the least amount of study. Most shops have expert financiers, expert designers, expert salesmen and expert purchasing agents—for everything except labor. The buying of labor is usually left to people whose special work is something else, with the result that it is usually done in a manner that is very unsatisfactory to buyer and seller. It is admitted to be the hardest problem we have to face in manufacturing to-day, and yet it is only considered when the manager "has time" or has "to take time," or on account of "labor trouble." The time to study this subject is not when labor trouble is brewing, but when things are running smoothly and employer and employee have confidence in each other.

Men as a whole (not mechanics only) prefer to sell their time rather than their labor, and to perform in that time the amount of labor they consider proper for the pay received. In other words, they prefer to work by the day and be themselves the judges of the amount of work they shall do in that day, thus fixing absolutely the price of labor without regard to the wishes of the employer who pays the bill.

While men prefer as a rule to sell their time and themselves determine the amount of work they will do in that time, a very large number of them are willing to do any reasonable amount of work the employer may specify in that time, provided only they are shown how it can be done and paid substantial additional amounts of money for doing it. The additional amount needed to make men do as much work as they can depends upon how hard or disagreeable the work is and varies from 20 to 100 per cent. of their day rate.

If the work is light and the workman is not physically tired at the end of the day he will follow instructions and do all the work called for if he can earn from 20 to 30 per cent. in addition to his usual day's wages. If the work is severe and he is physically tired at the end of the day he requires from 40 to 60 per cent. additional to make him do his work. If in addition to being physically tired he has been obliged to work under disagreeable conditions or in intense heat, he may require 70 per cent. or even 100 per cent. additional.

TASK WORK WITH A BONUS.

It is these considerations that lead to the development of the bonus system of paying labor, under which a man always gets his day's wages, and if he accomplishes the task in the time and manner specified, he is paid a bonus the size of which depends upon the severity of the work.

The easiest way to figure such a bonus is to make it a proportion of the time allowed; for instance, if from our time study we find that three hours is a reasonable time for a job that has usually taken from five to ten hours, we set three hours as the time limit and pay the workman one-third more, or for four hours, if he does the work in three hours or less. If he does it in exactly three hours he gets pay for four hours, or an increase of 33⅓%. If the work is done in 2½ hours he gets pay for four hours, or an increase in wages per hour of 60%. If the work is done in two hours his pay is still that which he would ordinarily get for four hours, an increase of 100%.

As I have said before, a proper task is always greater than the ordinary workman can perform at first, and must be such as only the most skilled can perform. On the other hand, when the more skilled have been earning their bonus for some time, and the less skilled begin to realise that the prize is real and worth striving for, they make every effort to attain it and rapidly improve in skill.

This increase in efficiency makes the payment of high wages possible, and it may be added that without efficient labor, permanent high wages cannot be paid indefinitely, for every wasteful operation, every mistake, every useless move has to be paid for by somebody, and in the long run the workman has to bear his share.

Good management, in which the number of mistakes is reduced to a minimum, and useless, or wasteful operations eliminated, is so different from poor management, in which no systematic attempt is made to do away with these troubles, that a man who has always worked under the latter finds it extremely difficult to form a conception of the former. The best type of management is that in which all the available knowledge is utilized to plan all work, and when the work is done strictly in accordance with the plans made. In other words, that management is best which utilizes labor in the most efficient manner.

The best mechanical equipment of a plant that money can buy avails but little if labor is not properly utilized. On the other hand, the efficient utilization of labor will often overcome the handicap of a very poor mechanical equipment, and an engineer can have no greater asset than the ability to handle labor efficiently.

A NEW COPPER-DEPOSITING PROCESS.

By L. RAMAKERS.*

It has long been the aim of electro-metallurgists to increase the rate at which copper can be deposited in a smooth form without any considerable increase in voltage, which means increased power and corresponding cost. The object of increasing the rate at which copper can be deposited is therefore to reduce the capital outlay, and also the amount of copper under treatment, which is an item of great importance in wo[rks] of any size. The current density employed in [elec]trolytic refineries has been increased from [about] 8 or 10 amperes, as originally employe[d by] Messrs. Elkington and Messrs. Elliotts, of [Bir]mingham, England, to 20 amperes per [square] foot, as at present employed by the Ana[conda] Works, in America.

Various attempts have been made from t[ime] to time to further increase the current densi[ty by] using mechanical means. The best know[n of] these are the Elmore process, which emplo[ys an] agate burnisher, that continually traverses the surface of the copper being deposited, and the Dumoulin process, which employs a shee[t of in] rubber, the object being to insulate by co[ating] with grease the raised portions of the copp[er as] soon as the deposit becomes rough, so as to cause the lower portions of the copper to be built up to the same level.

Messrs. Sherard Cowper-Coles & Co., Ltd., of London, England, have recently introduced a new centrifugal process, in which a current density is employed of 200 amperes per square foot of cathode surface, the voltage at the terminals of the depositing cell being 0.75.

The Cowper-Coles process differs from the other processes already mentioned, in that the mandrel on which copper is deposited is revolved at a "critical speed."

It is found that for a given current density the mandrel must have a certain peripheral speed; the greater the speed the greater the tensile strength of the copper. The result of revolving the mandrel at this comparatively high speed is that every molecule, as it is deposited, is burnished or rubbed down so as to produce a tough, fibrous copper; the usual order of things is thus reversed, the present practice being to put the mechanical work into a mass of copper instead of treating each molecule as it is deposited. The centrifugal action plays an important part in the Cowper-Coles process, as it enables very impure solutions to be used; that is, solutions containing a considerable amount of foreign matter in suspension, as the impurities are thrown off by centrifugal force and the rubbing action of the electrolyte, thus preventing the formation of any nodules.

FIG. 1. A VIEW SHOWING THE CRYSTALLINE STRUCTURE OF NODULES.

Fig. 2. Copper Deposited on a Revolving Cone, Showing the Effect of Different Peripheral Speeds.

Fig. 3. Copper Deposited Below the Critical Speed.

Fig. 1 shows, under a moderate magnification, the way these nodules are built up, and the crystalline structure of the copper crystals formed at right angles to the surface on which the copper is deposited. When these nodules are removed by force and examined under the microscope it will be found that at the root of each there is a small speck of foreign matter. These specks of impurities are also found to cause corrosion of the finished copper tube or sheet, when subjected to salt water or other corroding agencies, as they are usually electro-negative to the copper.

The method employed for determining the critical speed for varying conditions is by use of a revolving cone, as shown in Fig. 2, from which it will clearly be seen how the nature of the copper varies according to the peripheral speed; at the smallest diameter the copper is rough and brittle, and at the larger diameter it is smooth

*36 rue Saint Georges, Brussels, Belgium.

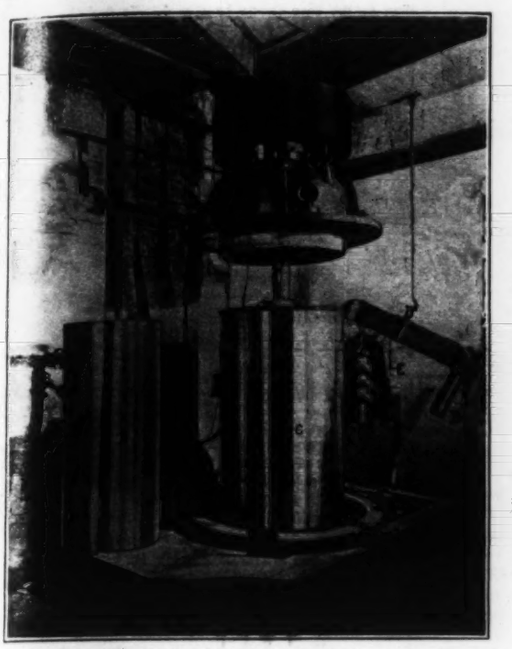


FIG. 4. PLANT FOR DEPOSITING LARGE COPPER CYLINDERS.

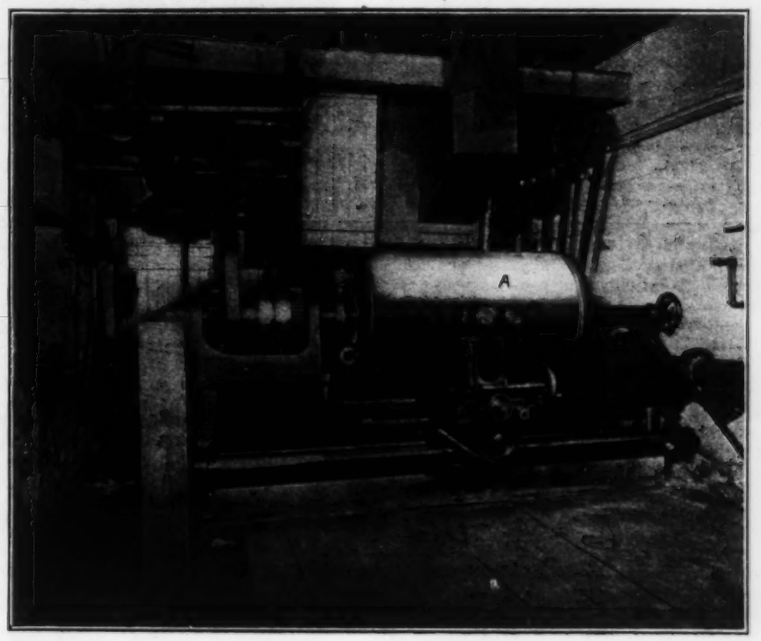


FIG. 5. APPARATUS FOR EXPANDING OF LARGE COPPER CYLINDERS.

and tough. Fig. 3 shows deposits of copper obtained before the critical speed is reached.

A recent application of the new process is the production of large copper cylinders for printing purposes, in connection with the textile industry. A plant for making these cylinders is shown in Fig. 4, and consists of a highly polished mandrel C, corresponding to the internal dimensions of the finished cylinder or continuous band that is to be produced. When it is desired to produce a sheet instead of a cylinder, an insulating strip is put down the side of the mandrel. A copper sheet thus produced is shown at D. The mandrel, or cathode, is driven at the desired speed by means of a belt and pulley. The anodes are cast copper, suspended on a copper ring, the current being led to them by means of the conductors A. The cathode connection is made by means of a mercury cup placed on the top of the driving spindle and the arm B, which fits on to the top bracket.

The cylinders are only about 1/32-in. in thickness, and are expanded off on especially constructed lathes, as shown in Fig. 5. A roller B is caused to traverse the surface of the deposited copper A, so as to slightly stretch or expand it. After the roller has passed over the copper once or twice it is found that the cylinder can be easily drawn off.

Another point of particular interest about the Cowper-Coles process is the method of making wire or strip. The apparatus employed is shown in Fig. 6, from which it will be seen that the vat is annular in construction. Such an arrangement has the great advantage that there are no working parts in the acid electrolyte, and that the mandrel can readily be withdrawn, and the amount of electrolyte required is greatly reduced. Such a vat is capable of making wire 3 or 4 miles in length.

The mandrel for the production of wire has a fine spiral scratch made on the surface (see Fig. 7); this scratch is angular, not rounded, so that the copper will divide. The effect of this scratch is to alter the crystalline structure of the deposited copper, and form a line of cleavage similar to that formed in cast metals, with sharp angles. A section of copper strip thus produced is shown in Fig. 8. The copper is deposited in the usual way, but when the end has once been started it can be unwound in a continuous strip, as shown in Fig. 7.

The copper obtained by this new process is very pure, even when very high current densities are employed and a solution containing much foreign matter in suspension, and gives a remarkably high tensile strength. Copper tubes without any drawing have been given a maximum stress of 17 tons, and a tube after drawing has stood a pressure of 3,000 lbs. per square inch (thickness of metal 0.063 in.) without showing any signs of distress. Sheets, without rolling, have given a maximum stress of from 28 to 34 tons per square inch.

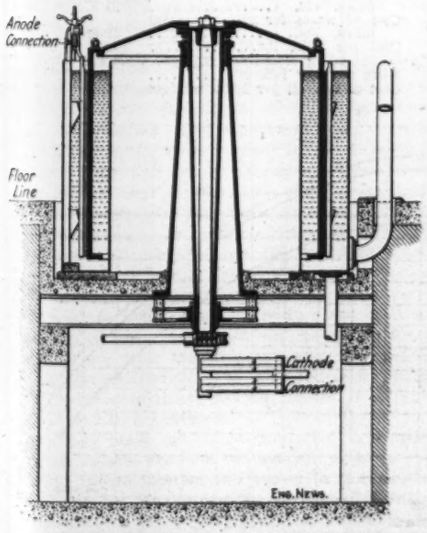


Fig. 6. Sectional Elevation of the Depositing Vat for Making Wire or Strip.

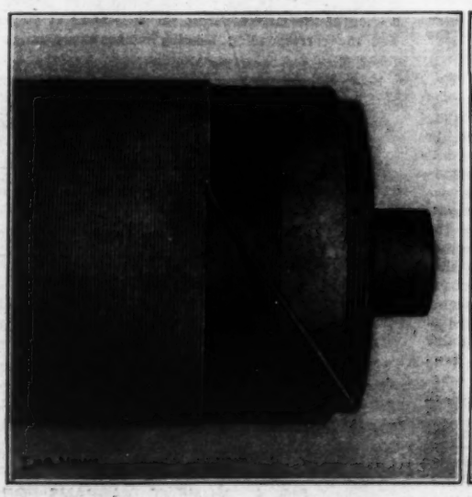


Fig. 7. Unwinding Copper Strip for Wire.

Fig. 8. Section of Copper Wire Strip.

DEFECTIVE GAS PIPE JOINTS AT BURLINGTON AND WINOOSKI, VT.

In our issue of March 7, 1907, in an account of a gas asphyxiation tragedy at Winooski, Vt., reference was made to gas leakage from some mains laid in 1906 by the Burlington Light & Power Co., in Burlington, Vt. Prof. J. W. Votey, of the University of Vermont, who supplied us the information on which our article was based, stated that the company used a "ground joint, bolted together." Prof. Votey has since written us on this subject as follows:

The so-called "ground joint bolted together" I find is a machined, tapered hub and spigot joint used on the pipe known as "Universal." The pipe is made in 6-ft. lengths, and the joints are formed by two bolts passing through lugs cast on both hub and spigot ends. The company here used a spring or cut washer under the nut. Great flexibility of the joint is claimed by the manufacturers, and it is suggested that the pipe be laid with the line joining the bolts horizontal in order to allow for settlement. The surfaces in contact are not deep—the machined surfaces are perhaps 1/8 or 3/16-in. deep (I did not measure them), and might permit of some movement if not drawn up too tight, but not of course to the extent that would be possible if the spigot end were made spherical. The pipe that has failed here has been by the breaking off of the lugs, which tells its own tale as to the flexibility of the joints. I do not know whether the company here laid the pipe with the bolts horizontal. The machined surfaces are covered with plumbago or red lead to prevent the action of rust.

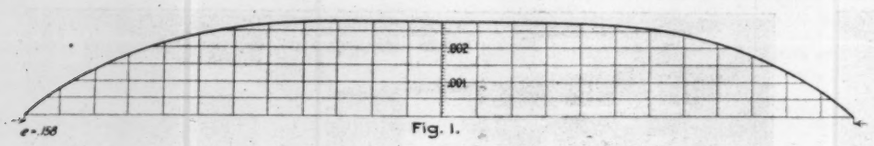


Fig. 1.

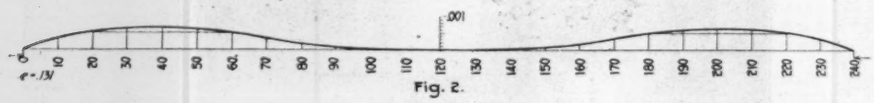


Fig. 2.

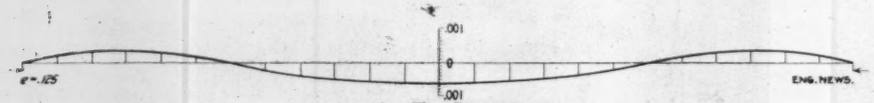


Fig. 3.

FIGS. 1-3. DEFLECTION CURVES OF HORIZONTAL COMPRESSION MEMBER WITH PIN CONNECTIONS, FOR THREE DIFFERENT VALUES OF ECCENTRICITY.

Fig. 1. Eccentricity $= \frac{w\,l^2}{8\,P}$.

Fig. 2. Zero deflection at Center; Eccentricity $= \frac{5}{48}\,\frac{w\,l^2}{P}$.

Fig. 3. Zero deflection at Quarter Points; Eccentricity $= \frac{10}{192}\,\frac{w\,l^2}{P} + \frac{217}{61,440}\,\frac{w\,l^4}{E\,I}$

On bringing this matter to the attention of the Central Foundry Co. (116 Nassau St., New York City), Mr. C. G. Beach, Manager, wrote us as follows:

The pipe laid at Winooski, Vt., was our Universal pipe. There was some trouble with the pipe, not through any fault of the pipe itself, but through carelessness in the installation of same, and because some of the pipe was a trifle defective in the machining and should never have been installed.

In regard to Mr. Votey's remarks on the spring washer, I beg to state that when we first started making and laying Universal pipe, some five years ago, we used a flat washer, and we have since found that a spring or out washer helps out in taking care of expansion and contraction, which is the reason that same is used. Our joint is of the male and female type, machined on a slight taper and drawn together with two bolts, on the same principle as the ground joint. It is admitted by engineers that our joint is far superior to any calked joint or screw joint that there is on the market.

In regard to the breakage of the lugs at Burlington, I would state that the joints were undoubtedly drawn up too tight, thus doing away with a certain amount of flexibility of the joint, but it has been absolutely proven in all installations of this pipe, either for gas or water, that the joint is much more elastic and flexible than either a calked joint or screw joint.

THEORY OF HORIZONTAL COMPRESSION MEMBERS WITH ECCENTRIC PIN CONNECTIONS.*

By JAMES E. BOYD.†

In a horizontal compression member there is a bending moment due to its own weight, which produces a deflection downward. If the pins are placed at the center of gravity of the cross-section, the line of thrust will fall above the center of gravity of all sections except those at the ends, making the member practically equivalent to an eccentrically loaded column.

To compensate for this bending moment due to the weight of the member, it is customary, in bridge construction, to place the pins a little below the center of gravity of the cross-section. This distance is usually such that the moment at the middle due to the weight is equal and opposite to that due to the thrust. If P = thrust, w = weight per inch, l = length, and e = the eccentricity of the pins,

$$P\,e = \frac{w\,l^2}{8}$$

no allowance being made for the deflection, which, in this case, is entirely upward.

This value of the eccentricity gives over-compensation at all parts except at the middle, if the upward deflection is neglected. Taking the latter into account, there is over-compensation at all points, including the middle. It seems that it would be better, therefore, to use a somewhat smaller figure. Owing to the fact that the compression in the top chords of a bridge varies from panel to panel while the size of the members remains constant, and to the fact that they must be connected to end-posts of a different cross-section, it is not practicable to approximate closely to any theoretical figure. However, there may be some interest in determining, as nearly as possible, what are the ideal conditions about which to approximate.

If x = distance of any point of the member from the left end, and y = the deflection at this point (positive being upward), the differential equation is

$$E\,I\,\frac{d^2\,y}{d\,x^2} = \frac{w}{2}\left(l\,x - x^2\right) - P\,(y + e) \ldots (1)$$

or

$$\frac{d^2\,y}{d\,x^2} + \frac{P\,y}{E\,I} = \frac{w}{2\,E\,I}\left(l\,x - x^2\right) - \frac{P\,e}{E\,I}$$

the solution of which is

$$y = C_1 \cos\sqrt{\frac{P}{E\,I}}\,x + C_2 \sin\sqrt{\frac{P}{E\,I}}\,x + \frac{w}{2\,P}\left(l\,x - x^2\right) - e + \frac{w\,E\,I}{P^2} \quad \ldots\ldots\ldots\ldots (2)$$

Using the conditions

$$y = 0 \text{ when } x = 0, \text{ and } \frac{d\,y}{d\,x} = 0 \text{ when } x = \frac{l}{2},$$

we get

$$C_1 = e - \frac{w\,E\,I}{P^2},\quad C_2 = C_1 \tan\sqrt{\frac{P}{E\,I}}\,\frac{l}{2}$$

Substituting in Equation (2) and reducing, we find the equation of the elastic curve

$$y = \left(e - \frac{w\,E\,I}{P^2}\right)\left\{\sec\sqrt{\frac{P}{E\,I}}\,\frac{l}{2}\cos\sqrt{\frac{P}{E\,I}}\left(\frac{l}{2} - x\right) - 1\right\} + \frac{w}{2\,P}\left(l\,x - x^2\right) \quad \ldots\ldots\ldots\ldots (3)$$

Fig. 1 gives the form of the curve when the eccentricity is proportioned by the usual rule

$$e = \frac{w\,l^2}{8\,P}$$

In Fig. 2 we have the case in which there is zero deflection at the middle. Here the deflections at all points and the corresponding bending moments are much less than in the case shown by Fig. 1. To find the value of e for this curve, we put y = 0 and x = ½ l in Equation (3),

$$\left(e - \frac{w\,E\,I}{P^2}\right)\left(\sec\sqrt{\frac{P}{E\,I}}\,\frac{l}{2} - 1\right) + \frac{w\,l^2}{8\,P} = 0 \quad (4)$$

whence

$$e = -\frac{w\,l^2}{8\,P\left(\sec\sqrt{\frac{P}{E\,I}}\,\frac{l}{2} - 1\right)} + \frac{w\,E\,I}{P^2}$$

expanding

$$\left(\frac{1}{\sec\sqrt{\frac{P}{E\,I}}\,\frac{l}{2} - 1}\right)$$

and reducing,

$$e = \frac{5}{6}\,\frac{w\,l^2}{8\,P} - \frac{w\,l^4}{3,840\,E\,I} - \frac{w\,P\,l^6}{387,092\,E^2\,I^2} - \ldots$$

The term $\frac{w\,l^4}{3,840\,E\,I}$ is practically negligible, and the following terms are still smaller, so that the eccentricity is practically five-sixths of that in Case I.

Fig. 3 represents the case in which the deflection is zero at one-fourth the length from either end. Using this condition in Equation (3) we find the value of the eccentricity to be

$$e = \frac{19}{24}\,\frac{w\,l^2}{8\,P} + \frac{217}{61,440}\,\frac{w\,l^4}{E\,I} + \ldots.$$

These curves are plotted for a member 20 ft. in length made of two 15-in., 40-lb. channels and one 20-in. by ⅝-in. plate. The value of I is 1,031; the weight per inch is 8.8 lbs.; E is taken at 29,000,000 lbs. per sq. in.; the compression is taken as 400,000 lbs. Fig. 4 gives the bending moments, the curves I, II., III. corresponding to the cases sketched in Figs. 1, 2, and 3. In Case I. the moment is all negative; the compressive stresses due to the moments are 576 lbs. per sq. in. at the ends and 10 lbs. per sq. in. at the middle. In Case II. the compressive stresses are 477 lbs. in the lower fibers at the ends and 63 lbs. in the upper fibers at the middle. In Case III. they are 454 lbs. in the lower fibers at the ends and 80 lbs. in the upper fibers at the middle. The direct stress is 12,900 lbs. per sq. in., so that these bending stresses have relatively little importance.

It would seem from inspection of these curves that the ideal condition lies between Cases II. and III. Instead of taking

$$e = \frac{w\,l^2}{8\,P}$$

it would be better to use the value

$$e = \frac{w\,l^2}{10\,P}$$

as the average figure for the eccentricity.

THE LOCOMOTIVE AND CAR MILEAGE RECORDS of the Louisville & Nashville Ry. are published monthly on large sheets, showing the figures for the present and previous year. From the January record we take the following figures:

	Passenger.	Freight.
Locomotives: Number in service...	137	209
Ave. miles per locomotive.....	5,579	3,883
Ave. miles per pint valve oil.....	83.92	55.35
Ave. miles per pint lub. oil.....	23.82	20.92
Cost of valve and lub. oil per 100 miles, cts.	21.57	26.94
Cost of waste for lub. per 1,000 miles, cts.	29.68	26.08
Coal per mile, lbs.....	112.88	178.76
Cars: (including sleepers); mileage..	3,771,492	28,074,701
Miles per pint lub. oil.....	404	384
Cost of lub. oil per 1,000 mi., cts	7.44	6.59

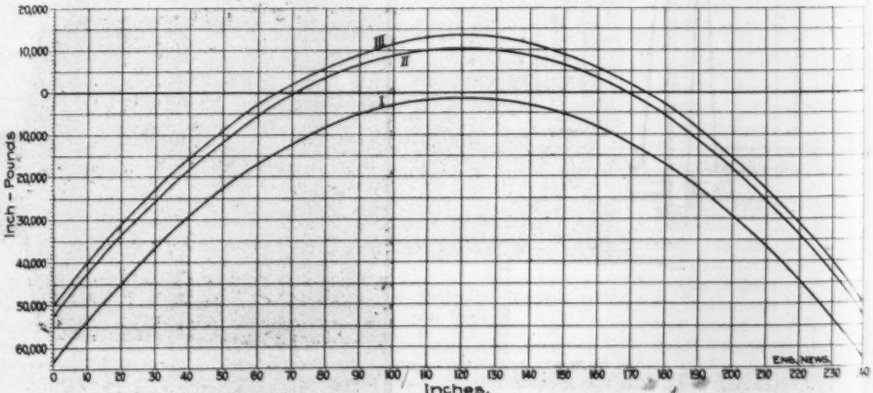


FIG. 4. MOMENT DIAGRAMS FOR CONDITIONS REPRESENTED BY FIGS. 1-3.
For chord section 20 ft. long, I=1,031 in.⁴, P=400,000 lbs.

*A paper presented before the American Association for the Advancement of Science at New York City, December, 1906.

†Professor of Mechanics, Ohio State University, Columbus, Ohio.

ENGINEERING NEWS

A Journal of Civil, Mechanical, Mining and Electrical Engineering

Published every Thursday by

THE ENGINEERING NEWS PUBLISHING CO.
220 BROADWAY, NEW YORK

BRANCH OFFICES
CHICAGO: 1636 Monadnock Block
WASHINGTON, D. C.: Home Life Building
ATLANTA: Candler Building
RUDOLF MOSSE, BERLIN AND HAMBURG, GERMANY

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The prominent part that percolating (or trickling or sprinkling) filters are taking in both American and British sewage works installations renders timely the extended review of the studies of such filters at the Lawrence Experiment Station, contributed to our columns this week by Mr. H. W. Clark. Those studies, in so far as they relate to percolating filters, as now conceived, cover a period of 8 years, but they were really begun 18 instead of 8 years ago. Some of the ideas suggested by the early studies of coarse grain or gravel filters at Lawrence were acted on by numerous workers in Great Britain, with the result that the percolating filter, as a practical means of treating sewage, was developed and widely used in England before it became much more than a laboratory device in this country. With the development of this filter abroad its study, along improved lines, was resumed at the Lawrence Experiment Station, with the results outlined by Mr. Clark.

In Great Britain, contact beds made great headway from about 1895 to say 1903, as contrasted with the popularity of intermittent sand filters in the United States. Many American towns have introduced contact beds on a small scale since 1898, partly because such beds were thought by the poorly informed to be a necessary accompaniment of septic tanks. But until the percolating filter was accepted here as thoroughly practicable the American predilection was for intermittent sand filters, wherever local conditions permitted. The high rates possible with percolating filters (2 to 5 times higher than with contact beds and 10 to 50 times higher than with intermittent sand filters), their great flexibility in design and operation, and yet, with all their differences, their similarities to intermittent filters, all combine to favor the rapid extension of intermittent filters in the United States. At present, the accepted formula is preliminary treatment by septic tanks or plain sedimentation, plus percolating filters, plus sedimentation for a brief period; with the omission of sedimentation where the discharge of a final effluent rather heavily laden with suspended matter, but non-putrescible, is permissible.

Although other problems connected with percolating filters are not all solved, perhaps the greatest future interest will center in the sprinkling devices for distributing the sewage. Revolving sprinklers of a few broad types, but of many varieties, are extensively used in England—thanks, in large part, to the enterprise of manufacturers, who are there called 'engineers." Fixed sprinklers have also been used abroad, beginning with some of the early installations, and appear to be gaining in favor. Here, percolating filters are so new and so few that only an apparent decided preference for fixed sprinklers can be asserted. The experimental sprinkler, of the fixed type, described and illustrated by Mr. Clark, is different from any that has previously come to our attention. Considerable experimental work on sprinklers has been described at various times in our columns (Columbus, O., March 29, 1906, p. 368; Massachusetts Institute of Technology, Aug. 16, Oct. 18, 1906; Baltimore, Md., and Waterbury, Conn., Feb. 28, 1907). Finally, attention may be called to the fact that while abroad the material most commonly used for percolating filters is clinker there are many indications that in America broken stone will be used instead, both because it is readily available in most parts of the country, which cannot be said for England, and because it does not crumble or break down and clog the beds, as does clinker.

Further particulars of the open-switch accident at Colton, Cal., which was discussed in our issue of April 4, are given in the letter printed below from Mr. J. Kruttschnitt, Director of Maintenance and Operation of the Southern Pacific Ry., in reply to a request for official information.

We commented last week upon the high speed at which the train entered the yard limits, and it now appears that this was in violation of rules; but with a train eight hours or more behind time it is not difficult to understand that the engineman might ignore rules regarding reduction in speed. It was presumably for this reason (among others) that the Texas legislature passed a law which has recently gone into effect, requiring the cancellation of trains which are more than a specified time behind their schedule. The train being canceled at the first division point, loses its rights and starts again under a new schedule. With trains many hours late but still retaining rights given it under the regular schedule, confusion and accidents are extremely likely to occur.

It will be noted that there was no protective equipment at this switch, and we believe nobody will dispute the position taken in the editorial in our issue of March 28, to the effect that every switch in main tracks ought to be equipped either with interlocking switch and signal apparatus or with a distant signal automatically operated from the switch. A switch target is certainly not sufficient protection for main line traffic, and the cost of simple and effective safety apparatus is small as compared with its value as an insurance against accident and loss. Mr. Kruttschnitt's letter follows:

> The accident happened at an industry switch, leading to the plant of the Armour Fertilizer Co. The switch engine had gone in on this track to do necessary switching some 15 minutes before the accident occurred, and the crew failed to close the main track switch, or protect themselves, as required by the rules. The engineman and fireman of this particular switch engine were fully informed as to the approach of the passenger train by a regular "31" train order which they held, advising them train No. 9 was running 9 hours 45 minutes late on schedule.
>
> The switch in question was not protected by a distant signal or safety device, as the track at this point is straight for a distance of some three miles, and the engineman of train No. 9 had an unobstructed view of the switch target, which showed red, indicating stop. In addition to this, there was a special bulletin restricting the speed of all trains within yard limits at Colton to 15 miles per hour. These instructions were apparently entirely disregarded by the engineman of the limited train, who evidently did not notice the position of the switch until too close to prevent accident.

The same accident also calls attention to the dangers incident to the working of switch engines on main tracks. While controlled to some extent by orders, they frequently run "wildcat" and simply under the control of the engineman without any special orders, except perhaps from a yardmaster. It is true that a stereotyped rule requires them to get off and be clear of the main track a certain number of minutes before the time of regular trains, but with trains habitually or exceptionally late (and in this particular accident the regular train was nearly ten hours late) this rule soon fails to be observed, and the men take all kinds of chances in making the movements necessary to their work. The engineman of the regular train has, in the great majority of cases, no knowledge of what conditions exist in a yard or at a yard entrance as he approaches, perhaps at high speed. Collisions of trains with yard engines improperly occupying the main track are frequently reported, occurring sometimes at large city yards and sometimes at small outlying towns, but the chances continue to be run almost daily. In very many cases, the necessity for a switch engine to occupy or work upon a main track may be greatly reduced by a proper arrangement of tracks, and this is one of the many points to be considered in the design of yard layouts. But certainly it should not be allowable for such an engine to occupy the main track until a signal is displayed which will give ample and sufficient warning to a regular train.

The Colton accident happened within the yard limits; but every disaster at an open switch suggests that the number of such breaks in the main line, particularly on railways running high-speed through trains ought to be as few as possible. There is, however, constant pressure to increase the number of such switches, to enable new industries located away from regular stations, to have their own private siding. In the "public service" commission law now pending in the New York legislature, the following provision is found:

> A railroad corporation upon the application of any shipper shall provide side-track and switch connection with any line of its railroad, wherever such side-track and switch connection is reasonably practicable, can be put in with safety, and the business therefor is sufficient to justify such connection and the maintenance thereof.

We do not at all question the necessity of such a clause in the law, if railways are to be subject to effective Government supervision to prevent discrimination between patrons; but in the execution of any such law, the safety of the traveling public should have full consideration as well as the claims of the private industry seeking to instal the switch.

We have often commented on the lack of literature on water-works operation. Most of such literature as is available is to be found scattered through the engineering journals and the proceedings of the various water-works associations. The American Water Works Association has issued a special invitation to its members to contribute short, practical, water-works experiences, for presentation at its next annual meeting, which will be held at Toronto June 11-15, 1907. We take pleasure in giving publicity to this request and to the topics suggested. The latter are as follows:

> For instance, tell us of some unusual leak, how caused and how repaired; the laying of a line of pipe in some difficult place, under a railroad or in treacherous soil, across a small stream or in marsh; the making of lead joints where the trench could not be kept dry, or in old lines, to make a new connection or repair a leak, when the valves would not shut tight; how you protect pipes under railroad tracks, or repair leaks in the same; how you protect shallow services or hydrant branches from freezing; trouble with anchor ice, and how overcome or avoided; thawing service pipes, hydrant branches or mains; break-down of pumping engines, cause, and how overcome or repaired while in service; trouble with boilers and how overcome; means adopted to improve boiler or engine efficiency; pump slippage, how discovered and how corrected; any unusual occurrence about the pumping station; cleaning obstructed mains and services; detection of improper use of water, and the remedy applied or penalty imposed; any unusual experience with meters, setting in difficult places, repairing, reading, etc.; experience in collecting water rates; something about your office records, records of pumping, services, pipe lines, etc.; description of any new tools or appliances you have tried and the result; new packing for pumps; material for pipe joints; lead flange connections for services versus wiped joints; legal controversies or decisions.

Certainly there is no capable water-works engineer or superintendent who cannot write something on some one or more of these subjects that would be of material benefit to the water-works fraternity. We hope that the request for practical experiences will meet with a hearty response.

The Engineering Societies' Building in New York City, which was completed at the beginning of the present year and is now occupied by the three "founder societies," is to be formally dedicated with appropriate ceremonies next week. The occasion promises to be one of the notable events of the year in engineering circles. The program of the dedication exercises covers four days of the week, from Tuesday to Friday, inclusive. The formal dedication is to take place on Tuesday afternoon, and the program includes an address by Mr. Carnegie, the donor of the building, and an oration by President Hadley, of Yale University, on "The Professional Ideals of the Twentieth Century." On Thursday and Friday, sessions are to be held by the several founder societies for the presentation and discussion of professional papers. Receptions, excursions, etc., have been provided for to make the week socially attractive. The membership in the three founder societies devoted to Mechanical, Mining and Electrical Engineering is now between eleven and twelve thousand, and a large attendance at the meeting next week may be counted on.

The fact that a chimney of any particular type of construction is blown down by a heavy wind is not necessarily an indication that this type is in itself defective or dangerous, especially if the chimney in question is but one out of a large number of the same type. It appears, however, that a wreck of a reinforced-concrete chimney by a wind storm, recently reported in our columns, is being used as an argument against concrete chimney construction in general. This material being comparatively new in chimney construction has to encounter not only the prejudices and conservatism of purchasers, but also the sharp competition of its older rivals, whose field it invades. Being new, it also necessarily attracts more attention, so that its failures may be noted and recorded where those of similar structures of other material might pass unnoticed.

In the severe wind storm at Chicago on March 27, three steel chimneys and a 110-ft. brick chimney were blown down. The latter accident is noted elsewhere in this issue. It would not be reasonable, however, to argue from these accidents that steel or brick chimneys are necessarily or generally dangerous. It is stated that nearly 300 chimneys of reinforced-concrete construction have already been built, and we know of no evidence that this type of chimney is in any way inferior to others. At least the accident referred to has not shown it, since chimneys of other materials have likewise suffered in high winds.

CONCERNING A RAILWAY PASSENGER RATE OF TWO CENTS PER MILE.

A bill has passed the Pennsylvania legislature and on April 5 received the Governor's signature fixing the maximum rate of passenger fare on all steam railways within the State at 2 cts. per mile. In numerous other States, agitation for similar legislation has been particularly active for a year or more past. If such a law is enacted in Pennsylvania, where—to speak frankly—railway influence in shaping legislation has been more effective than in any other State of the Union, there can be no doubt that similar laws are to be expected in many other States.

The question arises, therefore, what attitude ought the railways to take toward such legislation? Is that rate a "reasonable" one, or is it so "unreasonable" that there is hope of success in an appeal to the courts by the railways on the ground that such rates are so low as to confiscate the property of railway stockholders?

The first thing to be said regarding such a law is that it is on the face of things unreasonable to subject all railways to one uniform rate. A main line may be able to earn large profits from passenger business at a 2 ct. a mile rate, while a branch line in thinly settled country may carry passengers at a loss even at a rate of 5 cts. per mile or more. Whatever divergent opinions may be held as to railway rates, all agree that a minimum is fixed by the cost of performing the service. A railway must earn enough at least to pay its operating expenses, including the maintenance of the property, or it must, sooner or later, be abandoned. Any rate too low to permit earnings sufficient for the railway to continue as a "going concern," therefore, is *prima facie* unreasonably low. There is a very large mileage of branch lines on which passenger service to-day is carried on at a loss. Where these lines are owned and operated by independent companies, it is manifest that some relief must be afforded from the sweeping legislation above noted or serious harm will be done, not only to these small railway companies, but to the communities which rely on them for transportation.

The case is admittedly somewhat different where these branch lines form parts of a large system. Here it may be argued that the company can make up on its main line for the losses that it sustains on its branch lines. While the company may run its branch line trains at a loss on the 2 ct. a mile rate, it will earn large profits on its main lines at this rate. Whether the latter contention is correct or not, we will pass for the moment. The important point to note is that this argument will probably be sufficient to convince legislators. In the Pennsylvania legislature a bill has already been introduced to exempt railways less than 40 miles in length from the provisions of the law just noted, and it is likely to become a law; but there is little likelihood that it will apply to the branches controlled by the large systems.

If passenger traffic were like freight traffic, and moved only as a matter of business or necessity, then it might be closely figured how much a reduction of the average passenger rate would mean in reduction of earnings; but the volume of passenger traffic is very largely influenced by the rates of fare. Where passenger traffic does not pay it is solely because there is not traffic enough. The average gross earnings per train mile of a passenger train in the United States as a whole is only $1.16; but the average passenger locomotive is capable of hauling a trainload of 500 to 1,000 passengers, which at a 2 ct. a mile average rate would mean earnings of $5 to $10 per train mile. If then the reduction and simplification of passenger rates means increased travel, the gross earnings may be raised instead of lowered.

The theory on which passenger rates on steam railways are generally based at the present time is that the fare should vary according to what the traffic will bear. The justice of this theory can be successfully defended. It can be shown, for example, that the railway has to run regular trains at all hours and in all weathers, many of which necessarily run at a loss, and that its rates of fare must enable it to earn a large profit on the well-patronized trains to compensate for losses on others. The patron who rides on a regular train is not only paying for that ride but his proportion of the cost of regular service. It is worth something to him to be able to take the journey on any day of the year, even if he does not actually travel at all. The railway company may reasonably charge more for its regular service than for service on special excursion trains, run at special times and so loaded that the cost of hauling a passenger a mile is only a small fraction of that in regular service.

In the working out of this theory of charging what the traffic will bear, however, there has grown up an amount of complication and red tape that appears in serious need of overhauling. For example, on most roads with a fair amount of traffic mileage tickets are now obtainable which are sold, with few exceptions, at the rate of 2 cts. per mile. Originally these tickets were sold with a view of limiting their use to the wholesale buyer of transportation, and under divers pains and penalties they were forbidden to be used except by the purchaser and the members of his immediate family (a term capable of much elastic interpretation), or the members or employees of his business firm. To expect conductors to enforce these limitations, however, was too much, and as they became a dead letter they were gradually abandoned and mileage tickets were made good to the bearer. As a result has been a very general use of mileage tickets by short distance travellers and the establishment of private renting agencies for mileage tickets which do a thriving business at a uniform charge of ¼ ct. per mile.

There is perhaps no more striking illustration than this of the great advantage to the railway companies of simplifying and unifying passenger fares. Here is a large section of community paying ¼ ct. per mile, or at the rate of one-eighth of the total receipts of the railway company for passenger traffic, simply to buy its transportation at retail instead of at wholesale, and with all the bother besides of obtaining and returning mileage tickets from the dealers. If the railway wished to save this ¼ ct. per mile for its own treasury it might readily have done so by putting on sale 100-mile books at $2.25; its patrons would have paid no more for their service and travel would have been stimulated by the greater convenience of the tickets.

There is, however, much to be said for going a step farther and wiping out all the old-time distinctions between through rates and local rates, and between the wholesale and the retail buyer of passenger transportation. As we have noted above, compulsory legislation to reduce passenger rates to a uniform basis of 2 cts. per mile is the order of the day. The opportunity of the railway companies is to anticipate such legislation wherever it can reasonably be done; and this applies, we believe, to a very much greater extent of territory than has been hitherto supposed.

Already progress in this direction is being made. The New York Central Lines have recently adopted a new mileage ticket, good on over 7,000 miles of its lines east of Buffalo. The New York Central also sells at the same rate of 2 cts. per mile 500-mile books good over the New York Central & Hudson River R. R. and leased lines. In 1901 the railways of Massachusetts, at the suggestion of the State Railroad Commission, introduced 500 mile books, and it is referred to by the commission as "a step in the direction of a general charge of two cents a mile for single trip tickets."

On the principal railway systems of New England, the New York, New Haven & Hartford, the Boston & Maine, and the Boston & Albany, the uniform 2 ct. a mile rate on all classes of tickets has been put in force during the past year, and the results, on the first named road at least, are said to be an actual gain in the net earnings of the railway company.

It must be understood that a reduction to a flat rate of 2 cts. per mile is actually no considerable reduction from average rates now charged. The average revenue per passenger mile is already down to 1¾ cts. in New England and the Middle States, where population is most dense, and it is below 2 cts. per mile in all the territory lying north of the Ohio and east of the Missouri rivers. A 2 ct. a mile rate or less is already in force on all commutation traffic, on nearly all mileage tickets, and on a very large proportion of long-distance journeys. The flat 2 ct. a mile rate will benefit chiefly therefore the local traffic, and it is precisely this class of traffic which most needs and will most readily respond to the stimulus of low fares and uniform rates.

It has long been a tradition of the railway business that the local traveller had to travel anyway, hence there was no object in offering him any inducements in the way of low fares or improved accommodations. The results of electric railway operation, however, have thoroughly proved the falsity of this old idea. Electric suburban and interurban railways are carrying passengers for a cent a mile or less and picking up profitable traffic where the steam railways with high rates and poor service ran their trains at a loss.

The tradition of steam railway service that fares must vary with distance, with classes of tickets, etc., were thrown to the winds by the

electric roads, and the object lesson taught is that uniform and simple fares may so stimulate traffic as to outweigh all the objections that can be brought against them.

In a recent argument before the Pennsylvania legislature, President Jas. McCrea of the Pennsylvania R. R. gave the following interesting figures as to the receipts of the Pennsylvania R. R. lines east of Pittsburg and Erie from various classes of passenger travel in 1906.

	Av'g. Rate per Mile.	P. C. of Total Business.
One-way tickets	2.51 cts.	51
Round trip and excursion tickets	2.009	27
Commutation tickets	1.061	9
Mileage tickets	2.00	13
Total average rate	2.055c.	100

The one-way tickets include apparently both through and local, and, as the former tickets are generally sold at little more than 2 cts. per mile, the local tickets are probably sold at about 3 cts. per mile. The proposition of a two-cent a mile flat rate, therefore, really affects the local travel and little else. It is this class of travel, however, as we have seen, which can in almost all cases be carried with very slight additional expense for train service or for rolling stock. The revenue from additional travel of this sort, therefore, will be nearly all clear profit.

Doubtless the introduction of a flat two-cent a mile rate would cause in most cases some falling off in net revenue at the start. It takes time to educate the travelling public to the use of new advantages; but the final effect on the traffic cannot be doubted. The travel habit grows all the time as opportunities for travel are increased. Even business travel is closely influenced by the cost of and facilities for such travel.

To summarize and conclude, therefore, the two-cent a mile rate cannot be justified for railways in thinly populated regions operated by independent companies. It can be supported as good business policy on all railways serving a population sufficiently dense to permit a large increase of traffic to result from lower local fares.

LETTERS TO THE EDITOR.

Expansion Joints in Concrete Basement Floors.

Sir: I would like to ask through the columns of your journal whether it is customary to put in concrete basement floors monolithic or "blocked off." The writer has seen monolithic floors laid in basement rooms where subsequent trouble arose by some of them cracking badly.

The rooms were heated to a temperature of about 70° F. while the work was in progress and while the concrete was setting. The average size of rooms was 20 × 20 ft.

The sub-grade of the floors was thoroughly rolled. The lower layer was 3 ins. thick, 1:3:5 mixture; top, 1 in. thick, 1:2 mixture. The floors were kept damp continuously for several days after being laid.

Have any of your readers experienced similar difficulty? What methods were employed to secure desirable results? What is the maximum size of monolithic concrete floor in which no cracks may be expected to appear?

Yours truly,
Earl D. Covell.

Fort Thomas, Ky., April 5, 1907.

A Government Public Works Department.

Sir: The copy of the President's letter to each member of "The Inland Waterways Commission," given in your issue of March 21, and your editorial comments in the issues of March 28 and April 4 show that a step in the right direction has been taken.

If this commission shall be the seed from which a Department of Public Works is produced, with the necessary organization to properly care for the present and construct the future government works, a change will be made that has long been needed.

What would be the present status of the Panama Canal work; the harbor and electric and steam railway conditions in the Philippines; the study of the transportation problem in Alaska, had there been, for the past few years, a well organized Department of Public Works in our General Government?

With such a department, the immense and ever-increasing appropriations for public works of all descriptions would be handled in a much more economical manner; the personnel of the department, or rather the character of the men employed by it on public works, would be raised and better work would be secured.

I hope that the Commission is but the forerunner of such an organization.

Yours respectfully, T. M. Ripley.

123 North Allen St., Albany, N. Y., April 6, 1907.

The Effect of Height of Center of Gravity on Lateral Pressure of Railway Vehicles.

Sir: In your issue of March 14, in replying to the question whether the height of the center of gravity of an engine above the rail affects the lateral pressure exerted on the outer rail on curves, you answer in the negative save as to its effect on impact. To me it seems that the position of the center of gravity affects the lateral pressure, for, obviously, the center of gravity could be placed where for a given speed it would just balance the engine on the outer rail; there would then be no pressure due to longitudinal slipping. This effect is perhaps not so very great, but if we examine its effect on the force tending to cause the rail to slip on the tie we shall find it far from negligible.

If we consider the flange pressure of the leading driver on the outer rail we find it due to three things: (1) the force necessary to cause the driver to slip laterally; (2) the force necessary to cause the other wheels in the rigid frame to slip; and (3) the centrifugal force, which is independent of the height of the center of gravity. The force tending to cause the rail to slip on the tie is the sum of the last two, and resisting this we have the spikes and the product of the weight of the leading driver on the outside rail multiplied by the coefficient of friction between the rail and tie. Now if we raise the center of gravity we lessen the force tending to cause the rail to slip and increase the resisting force.

These effects, though not negligible in the electric locomotive mentioned on page 298, are exceedingly great in the case of the steam locomotive mentioned on the same page.

Yours truly,
Wm. J. Johnson.

Tuxpan, Jalisco, Mex., March 23, 1907.

[The rail-pressure consumed in lateral slipping will be slightly reduced as the fraction of weight going to the outer rail is increased; for, the slipping of that wheel (or wheels) which bears against the rail is a self-contained action and does not tend to displace the rail, and as this part of the total slip action is increased the active remainder is decreased. The decrease will be small compared with the total rail-pressure.

The rail-pressure due to longitudinal slipping is less clearly defined. If all longitudinal slip occurs at the inner wheels *at all speeds* and under all conditions, we may reasonably conclude that as the load on the inner rail is decreased the pressure due to longitudinal slipping also decreases. But the modifying conditions are so many that, we believe, it does not seem justifiable to view the longitudinal slipping other than as a constant, not varying with speed.

In long vehicles like cars, resting on groups of trucks, the turning of the trucks which must occur at a curve introduces a wedging rail-pressure (outward on the outer rail at the front axle, toward the inside of the curve on the inner rail at the rear axle of the truck, on entering a curve; the reverse of this on leaving a curve). The amount of this pressure will depend on the nature of the bearing of body on truck. When high center of gravity and high speed force the body down hard on the outer side-bearing, the turning friction and hence the rail-pressure chargeable to it may be increased. This effect is opposite to that arising in the case of the lateral slip.

The influence of high center of gravity to increase the friction between outer rail and tie, hence to decrease the residual spike-shear, is clearly exhibited in the figures tabulated in the article printed on pp. 296 to 299 of our issue of March 14, 1907.—Ed.]

Tests of the Holding Power of Railway Spikes.

Sir: I read in the March 7 issue of your esteemed paper the account of the tests made by Prof. Webber, of the University of Illinois, on different rail fastenings.

I do not think it possible to draw a conclusion from the experiments Prof. Webber has undertaken. The wrenching out of a spike or a screw-spike by continuous effort with a special machine does not give the right test of the holding power of a rail fastening, the conditions on the track being different from those that can be realized in a laboratory. On the track, there is not a direct pull of the screw-spike by continuous effort nor is there lateral displacement such as can be obtained with the arrangement devised by Prof. Webber; moreover, there are other causes of destruction, such as hammering, the deflections and vibrations of the line under the influence of passing trains, which are not taken into account.

The only valuable tests of track fastenings are those made in the track itself under the ordinary conditions of traffic.

Great holding power is no doubt of importance for a rail fastening, but it is not all-sufficient. A good rail fastening, in my opinion, must have a certain amount of elasticity, ensure a strong and constant pressure of the rail or its support agaginst the tie; at least it must not be a cause of destruction of the tie.

I do not think anybody will contradict me if I say that the ordinary spike, besides not having sufficient holding power to answer the present requirements of traffic is very harmful to the tie. It is a well-known fact that most ties do not perish though decay, since they are chemically treated, but through the fastenings and especially through the spikes. As soon as the spike is unable to ensure a strong pressure of the rail on the tie and allows some play to exist, then begin the "hammering" and its destructive influence on the tie, which will have soon to be rejected.

The screw-spike is an improvement over the ordinary spike, and that superiority has been acknowledged by the International Railway Congress, held at Washington in May, 1905. However, the screw-spike is not yet an ideal rail fastening, its holding power in soft wood is not very great, it requires frequent retightening and it does not protect the tie against the destructive action of the rail or its support.

Such are the reasons which have led me to the invention of my helical linings for screw-spikes. I will not enlarge here upon the advantages of these linings, which are being used in large quantities by railway companies and are now sufficiently known to American engineers. I will only draw attention to the fact that a lining, besides increasing the holding power of a screw-spike, reduces to a great degree the destructive effect of the rail on the tie by ensuring a strong and constant pressure of the former on the latter. This fact is not the result of a simple test, but of six years' experience in the tracks of different railways.

The insertion of those linings is very easily and very quickly done on the track or at the works by means of a special machine, and facilitates a good fixing of the screw-spike. Should any of the readers of this paper feel interested in the subject, I shall be pleased to send them the paper I have recently published on my "Helical Linings."

The helical linings do not increase the cost of the ordinary screw-spikes. I am now selling screw-spikes fitted with linings at 4½ cts. apiece duty paid at New York or any Atlantic port, which is only ½-ct. above the average price given for screw-spikes in Mr. Webber's report. The small cost of the lining will be quickly repaid by the facility and security it gives to the fixing of the screw-spike and by the saving in the life of the tie.

I am, Dear Sir,
Yours truly,
Jean Thiollier, Ingénieur.

92, Boulevard Haussmann, Paris, France, March 22, 1907.

[While the test of actual use must be the final one to determine the value of anything, it can hardly be successfully maintained that laboratory tests are without value, particularly if they are made with a clear understanding of the practical conditions to be met in service.

It is probable that the resistance of a spike to direct pull is less important than its resistance to lateral displacement, and that its resistance when it is pulled out a half inch or so, as any spike is liable to be, is quite as important as its resistance when driven home.—Ed.]

Pitfalls and Variations in Reinforced Concrete Design.

Sir: The writer recently had presented to him for examination the design of a reinforced concrete building. While familiar with steel construction, he is somewhat of an amateur in reinforced concrete, and it was necessary for him to have recourse to the various books on the subject. The authors of these works are far apart in their conclusions, so much so that it does not seem safe to follow any single writer throughout. As you remark in your abstract of French Government Rules in your issue of March 21, "there is absolutely no authoritative American code of specifications or practice in existence."

In the first place, there is a considerable difference in calculating the strength of a simple beam. If, as Prof. Hatt and others claim, the compressive stresses in the concrete vary as the ordinates of a parabola, and the strength of the beam is based upon the extreme-fiber stress in the concrete, the beam is 17% stronger than if the compressive stresses in any fiber are directly proportional to the distance of that fiber from the neutral axis.

At this point it may be mentioned that the *last* edition of a book should be followed. The writer followed the calculations of a simple beam according to the example

given in the first edition of Buell and Hill in their book "Reinforced Concrete" dated 1904. The results obtained and the method given appeared to be radically wrong. He was saved from foolishly rushing into print in regard to the matter by having his attention called to the new edition of the book, where the chapter on beams and theories of flexure has been rewritten. For the particular beam in mind the allowable bending moment according to the later edition is double that given in the previous edition.

Unit stresses given by different writers vary greatly. It is true no general rule can be given. The values of different kinds of concrete differ and must be obtained by test. Still, to the lay mind it seems there should be a nearer degree of uniformity than at present.

Are beams to be figured continuous over supports? How shall the strength of the floor slab be calculated? On these two questions there is a wide range of choice, especially so if we consider the handbooks of dealers and the practice of designing engineers, as well as the technical literature on the subject.

A well-known handbook widely circulated, says that rectangular beams when incorporated in floor panels will have just about twice the capacity given by the formula for beams on knife-edge supports. At the same time, one of the best known text-books will allow an addition of only 25%.

How much of the slab shall be assumed as part of the beam? The "Regulations of the Bureau of Buildings of the Borough of Manhattan, New York City, in regard to the use of Concrete Steel Construction" says: "The floor-plate to the extent of not more than ten times the width of any beam or girder may be taken as part of that beam or girder in computing its moment of resistance." This seems to be foolish. Mr. Reid, in his book "Concrete and Reinforced Concrete Construction," who has "Assistant Engineer, Bureau of Buildings," after his name on the title page, writes, on page 312, "It is evident that under normal conditions, ten times the width of the stem is far too liberal an assumption, while a value of three is much too small; a value of from four to six is probably about right to fit all cases without straining the concrete too high." Taylor and Thompson in their book "Concrete, Plain and Reinforced," write of the effect of the T-section as "somewhat problematical" and design their beams without reference to the slab.

The New York Building Regulations are explicit and definite in their requirements, and with the exception of the "break" just mentioned, seem to be conservative and safe. Some of their other requirements are:

Extreme fiber stress on concrete in compression	500	lbs. per sq in.
Shearing stress in concrete	50	" "
Concrete in direct compression	350	" "
Tensile stress in steel	16,000	" "
Shearing stress in steel	10,000	" "

The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

Beams and girders shall be considered as simply supported at the ends, no allowance being made for continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $\frac{WL}{10}$; the bending moment may be taken at $\frac{WL}{20}$ in the case of square floor plates which are reinforced in both directions and supported on all sides.

The strain in any fiber is directly proportionate to the distance of that fiber from the neutral axis.

The tensile strength of the concrete shall not be considered.

Concrete-steel may be used for columns in which the ratio of length to least side or diameter does not exceed twelve. The reinforcing rods must be tied together at intervals of not more than the least side or diameter of the column.

On the whole subject, what is authoritative, and where can it be found? With the design the writer had before him, he could find authority for reporting it amply strong, and authority seemingly of equal weight that would condemn it.

An expression of opinion from some of your readers qualified to write on the subject would certainly be welcomed.

At the same time, it may be pertinent to ask whether it is allowable to use a factor of two for the dead loads in a reinforced concrete structure. If so, why should a steel structure be calculated for a safety-factor of four for its dead load?

Also, in view of some recent failures of concrete columns, is it not partly true that "one of the best ways to design a concrete column is to build it of cast-iron or steel?" Exception is taken by the writer to cast-iron in the quotation.

Yours very truly,
R. F.

New York City, March 28, 1907.

GRINDING RAILS ON ENGLISH STREET RAILWAYS.

It is becoming a very general practice on street railways in England to true up the rails, especially at the joints, by grinding the heads. This is done either by a car fitted with apparatus for driving emery or carborundum wheels, or by a grinding shoe attached to a car truck. The treatment is used to finish off the joints in new track and special work, where the rails are rigidly embedded and anchored in concrete; it is also used to trim lipped or worn joints and to take out the transverse grooves or corrugations in the rail heads, which appear to be a very common trouble in England. Fig. 1 shows the Brown & Costa machine of this kind, equipped

FIG. 2. PLANING AND GRINDING MACHINE FOR RENEWING RAIL JOINTS.
Railway & General Engineering Co., Nottingham, England, Makers.

with an electric motor for operating the grinder. It has a steel frame mounted on flanged wheels, and provided with brakes for holding the car while the grinding is in progress. Each of the carborundum wheels is carried by a compound slide, and can be adjusted vertically, longitudinally and transversely. The axle of the grinding apparatus is driven from the motor by a flexible steel shaft. The machines may also be fitted with a gasoline engine, or with both engine and motor. They are in use on the street railways of London, Nottingham, Halifax and other cities.

In street railway track, as in steam railway track, there is a tendency of the wheels to cut out or wear away the rail-head just beyond the joint at the entering end of the rail. This, of course, cannot be made good by grinding, but experiments are being made in the way of planing away the rail-head and fitting a renewable piece of hard steel, secured in place by dovetailing. Fig. 2 shows the Brown & Costa machine for this work, and it is operated by current

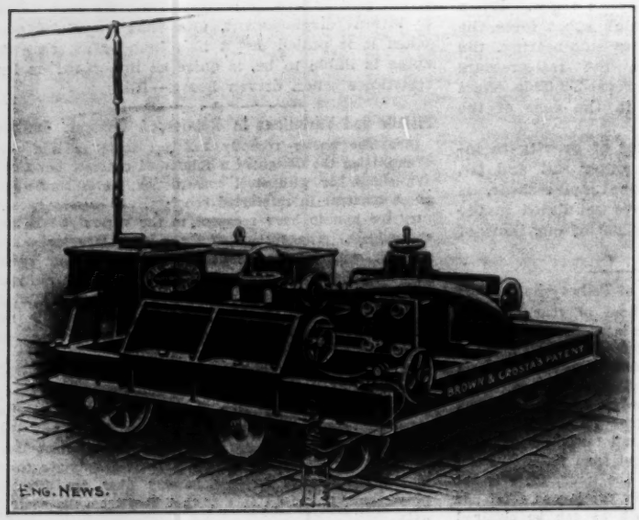

FIG. 1. STREET RAILWAY TRACK GRINDING MACHINE.
Railway & General Engineering Co., Nottingham, England, Makers.

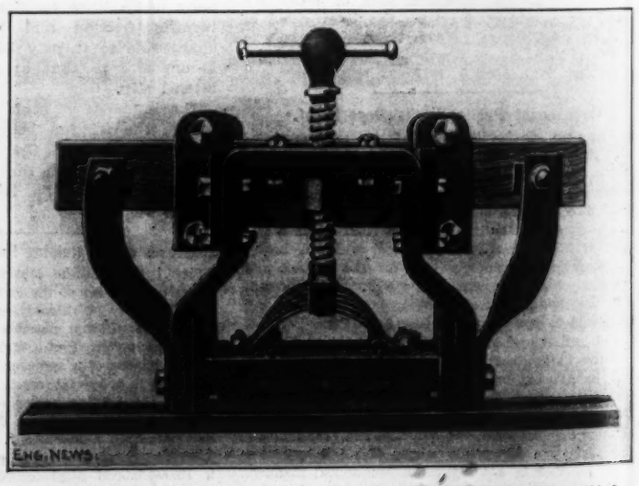

FIG. 3. RAIL GRINDING DEVICE FOR STEAM AND ELECTRIC RAILWAYS.
National Rail & Tramway Appliances Co., Liverpool, England, Makers.

taken from the trolley wire by a connection attached to the bamboo pole. The rail-head has been planed off just in front of the further rail clamp. Lying on the ground beside the rail is the attachment with grinding wheel by which the same machine can be used for facing off the rails and wear plates. Both of the machines described above are among the specialties of the Railway & General Engineering Co., of Nottingham, England.

In Fig. 3 is shown a rail grinding apparatus adapted to be attached to the truck of an electric car, the frame carrying a shoe or block of abrasive material which is held upon the rail with any desired degree of pressure by the spring and screw. An advantage claimed over machines using rotary grinders is that the block is long enough to ride upon the crests of the hollows, while the grinding wheels may follow the crests and hollows and thus tend to increase the corrugations. This device is in use on the street railways of Liverpool and Portsmouth, and also on the Liverpool elevated railway, and it is stated that it can take the corrugations out of half a mile of track in one night. It is built by the National Rail & Tramway Appliances Co., 12 Taylor St., Liverpool, England.

NOTES FROM ENGINEERING SCHOOLS.

McGILL UNIVERSITY.—The Macdonald engineering building, the gift of Sir William Macdonald, was completely destroyed by fire April 5. The loss is placed at $750,000, but the building was only insured for $420,000. The building was five stories high, with a large glass gallery on the upper story. The fire originated on the third floor at about the center of the building, from unknown causes. The building was opened in 1893 and contained much expensive machinery, instruments and models, including the famous Realeaux collection of kinematic models, said to be the finest in America.

UNIVERSITY OF COLORADO.—The third annual inspection trip of the senior and junior classes of the College of Engineering was held March 25-30. The party left Boulder, Colo., Monday morning, March 25, and stops were made at Pueblo, Portland, Canyon City, Cripple Creek and Colorado Springs, Colo. During the trip the plants of the Minnequa Works of the Colorado Fuel & Iron Co., at Pueblo; the electric light and power plants, pumping stations, roundhouses, bridges, etc., of Pueblo, Canyon City and Colorado Springs; the Portland Cement Co.'s Plant at Portland; the Skaguay Power Plant at Victor; the Elkton Mine, the Gold Coin Mine, the Portland Mine and Power Plants at Colorado Springs, and the Hydro-Electric Plant at Manitou were inspected. The party was made up of 20 seniors and 34 juniors, and was under the direction of Prof. M. S. Ketchum, Dean of Civil Engineering; Prof. H. S. Evans, Electrical Engineering; Prof. J. A. Hunter, Mechanical Engineering, and Mr. H. C. Ford, Instructor in Civil Engineering.

CARNEGIE INSTITUTE AND TECHNICAL SCHOOLS.—Mr. Andrew Carnegie announced April 5 an additional gift of $6,000,000 to these institutions. The income from $5,000,000 is to be applied by the trustees as they deem best, to the support of the Technical Schools, Art Department, Museum, Music Hall, Librarian's Schools, and such other classes or schools as may later be established. The remaining $1,000,000 is to be used in constructing new buildings for the Technical Schools. This last gift raises the total endowment to $9,000,000, of which $6,000,000 is for the Institute, and $3,000,000 for the Technical Schools. Mr. Carnegie's gifts to these institutions now amounts to $19,620,000.

The eleventh celebration of Founder's day and the dedication of the new building of the Carnegie Library and Institute will occur April 11-13. For this occasion Mr. Carnegie has invited many prominent persons to be his guests. The list includes the names of Sir Robert S. Ball, Lowndean Professor of Astronomy at Cambridge University; Prof. John Rhys, Master of Jesus College, Oxford; Provost James Currie Macbeth, Mayor of Dunfermline, Scotland; Baron D'Estournelles de Constant, a member of the French Senate; W. T. Stead, Editor of the Review of Reviews; Lieutenant General Alfred F. J. L. Loewenfeld, personal representative of Kaiser William; Herr von Hoeller, former Prussian Minister of Commerce and Industry; Baron Deschamps, Minister of State, Belgium.

The dedication will begin with a reception by Mayor George W. Guthrie, of Pittsburg, and will conclude with a visit to the Homestead Steel Works of the Carnegie Steel Co. Mr. Carnegie and his distinguished guests will make addresses during the dedication, and honorary degrees will be conferred on the foreign guests by the Western University of Pennsylvania.

FIRE IN THE ERECTING PLANT of the Church Street Terminal of the McAdoo Tunnels in New York City, on April 3, 1907, caused an estimated damage of $50,000 and for a time endangered the lives of a hundred or more caisson workers. This terminal, a description of which was published in Engineering News for Jan. 3, 1907, is to be founded on the solid rock, which is found at this point at a depth varying from 50 to 110 ft. The work now going on consists in sinking more than 100 caissons. The fire broke out in an oiling room, which stands on timber stilts in the middle of the excavation, and soon spread to the engine rooms supplying air to the caissons, being fed by the timber upper works of the caissons and the immense amount of derricks, bracing and other timbering all over the site. The alarm was rapidly spread to the caisson workers, who were nearly overcome from the smoke forced down to them from the pumps, which were in the midst of the fire. Although some of the engineers had to leave their engines on account of the flames, thus causing men to climb out of the deep caissons on the ladders. The entire force was rescued with but a few minor accidents. The work will be retarded about 30 days as a result of the damage.

FOUR MORE ATTEMPTS TO WRECK TRAINS on the Pennsylvania R. R. system have occurred since our last issue went to press. A second attempt to wreck the "Chicago Limited" was made at Pittsburg April 4, but was unsuccessful. The fish plates were removed from the rails, but the wreckers evidently did not have time to remove enough spikes to permit of moving the rail, thus ditching the train. On April 7 the "Cleveland Flier" was ditched at Hudson, O., by some one removing fish plates and spikes from the rails. This attempt was made in a narrow cut, and when the locomotive and baggage car left the rails they struck the side of the cut and little damage was done. The sleepers and day coaches did not leave the track. An attempt to wreck a fast passenger train at East Brady, Pa., was made April 7 by fastening a tie across the rails. The pilot of the locomotive tore the obstruction loose and no damage was done except to the pilot. An attempt to wreck a fast freight was made at Alliance, O., April 8, by suddenly throwing a switch and switching the train to a siding loaded with cars. No damage was done, however, as the train was brought to a standstill before striking the sidetracked cars.

A TRUST FUND of $120,000 for the establishment of what are to be known as the "Frank Thomson Scholarships" has been accepted from Miss Annie Thomson, Mr. Frank Graham Thomson, and Mr. Clark Thomson, by the Directors of the Pennsylvania R. R. Beginning with the year 1907 two scholarships, each for the annual amount of $600, will be awarded, and each year thereafter two more will be assigned. By this arrangement the fund will continuously keep eight men in college, each award being good for four years.

The scholarships will only be open to sons of Pennsylvania employees, and in order to receive an appointment the applicant must pass a competitive examination corresponding in general to the entrance examinations of the scientific departments of the higher institutions of learning.

FIRE DESTROYED the Hudson River steamer "City of Troy," of the Citizens' Line, at Dobbs Ferry, N. Y., April 5. The boat left New York City Friday evening on its regular run to Troy, N. Y., with 65 passengers on board. When off Yonkers, at about 9 P. M., the boat was discovered to be on fire, but it was fully an hour later before Captain Chas. H. Bruder was able to make a landing and discharge his passengers. All persons on board were safely landed, but the cargo, including seven horses, was destroyed. The "City of Troy" was a sidewheel steamboat, 280.6 ft. long, 38 ft. beam, 10 ft. draught, and with a gross tonnage of 1,527 tons. She was built at Brooklyn, N. Y., in 1876, but was remodeled about 13 years ago. Defective wiring is said to have caused the fire.

A HEAVY EARTHQUAKE damaged the city of Bitlis, Turkey, on March 29, according to reports from missionaries. Perhaps ten per cent. of the houses of the city were ruined by the series of shocks. About at the same time the statement has come from the seismological observatory at Laibach, Austria, that earth movements in the last few months have totalled below the average, and that larger movements may therefore be expected.

A TORNADO swept over portions of Louisiana, Mississippi and Alabama April 5, doing some $500,000 worth of damage to property and killing a score of people. At Alexandria, La., about 100 buildings were wrecked. The insane asylum at Jackson, La., was destroyed, three inmates killed and many others injured.

A BRICK CHIMNEY at a Chicago factory was blown down during a high wind on March 27. The chimney was 4 ft. diameter and 110 ft. high, at the plant of the E. J. Davis Planing Mill Co., 241 W. 21st St., Chicago, and was of ordinary brick construction, built a few years ago at a cost given as $2,000. The portion blown down wrecked an adjoining one-story building occupied by the Clinton Glass Co., going through the roof and the timber floor and carrying away part of the walls. We are informed by the Weather Bureau that the wind velocity recorded for that day was 48 miles an hour.

THE NEW MANHATTAN TERMINAL OF THE Brooklyn Bridge, described in our issue of Jan. 31, 1907, is to be commenced May 1, 1907. Notice to vacate has already been given to all occupants of buildings in the zone of work. The terminal is expected to be in operation by Jan. 1, 1908.

EXCAVATION FROM THE CULEBRA CUT during the months of March amounted to 815,270 cu. yds., according to official returns. This is 177,000 cu. yds. in advance of the best previous monthly record.

PERSONALS.

Senator John Hinchliffe has resigned as a member of the Passaic Valley Sewerage Commission.

Mr. C. L. Graves, General Manager of the Chihuahua & Pacific Ry., has resigned to engage in the mining business.

Mr. O. O. Winter has been appointed General Superintendent of the Grand Trunk Ry., with office at Winnipeg, Man.

Mr. Fred. Giddings has been reappointed City Engineer of Atchison, Kan. He has held the position for 11 years, and his new appointment is for two years.

Mr. W. S. Shields, consulting engineer in municipal and civil engineering work, has removed from 1715 Marquette Building, Chicago, to 1201 Hartford Building, Chicago.

Mr. J. W. Morrison has been appointed Superintendent of the Union Depot at St. Paul, Minn., to succeed Mr. Joseph Strawhorn, resigned to become General Manager of the South St. Paul Terminal.

Mr. Glenn D. Holmes, M. Am. Soc. C. E., Engineer of Water Supply, New York State Barge Canal, has resigned to accept the position of Engineer in charge of sewer construction for the city of Syracuse, N. Y.

Mr. J. F. Porterfield, Superintendent of the Yazoo & Mississippi Valley R. R., at Vicksburg, Miss., has been appointed Superintendent of the Louisiana Division of the Illinois Central R. R. He is succeeded by Mr. A. C. Ferguson.

Mr. Mason B. Starring, formerly Vice-President of the Chicago City Ry., of Chicago, Ill., has been elected President of the Northwestern Elevated R. R. of that city. He succeeds Mr. Clarence Buckingham, who becomes Vice-President.

Mr. Le Roy Churchill Chowning has been appointed Chief Mechanical Engineer of the Corning (N. Y.) Water-Works. He is a graduate of the Virginia Polytechnic Institute and was lately employed by the National Meter Co., of New York City.

Mr. J. P. Newman has been appointed New England advertising representative of Engineering News, succeeding Mr. B. D. Butler, transferred to Chicago. Mr. Newman will have his headquarters at the New York office of Engineering News.

Mr. E. W. Myers, Assoc. M. Am. Soc. C. E., Engineer, U. S Reclamation Service, has secured leave of absence for a year and has opened an office for the practice of hydraulic and municipal engineering in the Arcade Building, Greensboro, N. C.

Mr. William C. McKeown, of Denver, has been appointed Assistant Superintendent of the Wyoming Division of the Union Pacific R. R., at Cheyenne, Wyo., to succeed Mr. A. F. Vicksroy, who has been appointed Superintendent of the Colorado Division of the Denver & Rio Grande R. R.

Mr. B. D. Butler has been appointed Western adver-

tising representative of the Engineering News Publishing Co., succeeding Mr. M. C. Robbins, who recently resigned the position. Mr. Butler will have his headquarters at the Western office of Engineering News, 1636 Monadnock Block, Chicago.

Mr. George Hannauer has resigned as Superintendent of the Wiggins Ferry Co., of St. Louis, Mo., to become Superintendent of the Chicago, Indiana & Southern R. R., and the Indiana Harbor R. R. Mr. Charles Burlingame succeeds Mr. Hannauer as Superintendent of the Ferry company.

Mr. W. R. Jennison has severed his connection with the Lane & Bodley Co., of Cincinnati, Ohio, as their southern representative, and will now devote his time to the sale of Wheeler condensers, Weber steel stacks and Cochrane feed water heaters and separators. His address is the Prudential Building, Atlanta, Ga.

Mr. T. M. Connors, Assistant Superintendent of the Toledo & Ohio Central Ry., has been appointed Superintendent of the Kanawha & Michigan Ry., with headquarters at Charleston, W. Va. He succeeds Mr. W. C. Franz, who has been appointed General Manager of the Kanawha & West Virginia R. R., with headquarters at Charleston, W. Va.

Mr. Arthur P. Davis, Assistant Chief Engineer of the U. S. Reclamation Service, has been promoted to be Chief Engineer, to succeed Mr. F. H. Newell, who was recently appointed Director of the Service. Mr. Davis is a graduate of Washington University, St. Louis, and from 1898 to 1900 was in charge of the hydrographic work of the Nicaragua and Panama Canal routes. He joined the Reclamation Service immediately after the passage of the Reclamation Act, in June, 1902.

Mr. George Otis Smith, who has been acting as temporary head of the U. S. Geological Survey, has been appointed Director, effective May 1, to succeed Mr. Chas. D. Walcott, who was recently elected Secretary of the Smithsonian Institute. Mr. Smith became connected with the Survey soon after graduating from Colby College, in 1893. He received his doctor's degree from Johns Hopkins University in 1896. His work as a field geologist has included the states of Utah, North Carolina, New Jersey, Pennsylvania and the New England States, besides work in the Lake Superior region.

Mr. A. B. Crozier, M. W. Soc. E., has associated himself with Mr. R. C. Barnett, Assoc. M. Am. Soc. C. E., Civil Engineer, 510 Kansas City Life Building, Kansas City, Mo., as a Consulting Mechanical Engineer. He was recently connected with the Cudahy Packing Co., of Omaha, Neb., and previously with Schwarzschild & Sulzberger Packing Co. and Arnold & Co., in charge of electric light and power work, refrigerating and steam plants, etc. Messrs. Crozier and Barnett will give attention to designs and specifications for steel and reinforced concrete structures, foundation work, power plants, refrigerating and manufacturing plants.

Mr. Elbert E. Lochridge has been appointed Chief Engineer of the Little River water system, for Springfield, Mass. Mr. Allen Hazen, of the firm of Hazen & Whipple, 220 Broadway New York City, is Consulting Engineer for the new water system. Mr. Lochridge is a graduate of Beloit College. He also took a graduate course at the Massachusetts Institute of Technology, and has been connected with the water-works of Beloit, Wis.; Davenport, Iowa; Cedar Rapids, Iowa; Warren, Ohio; Binghamton, N. Y., and Brooklyn, N. Y. He is an associate member of the American Society of Civil Engineers, a member of the New England Water-Works Association, besides several other local societies.

Obituary.

Frank J. Sharp, a contractor of Germantown, Pa., died at his home in that town, April 3, aged 46 years.

Josiah B. Harthorn, a retired shipbuilder of New England, died at his home in Bangor, Me., April 6, aged 78 years.

Frederick Black, a civil engineer in the employ of the Tidewater R. R., committed suicide at Roanoke, Va., April 4.

John Joseph Riley, head of the Brooklyn Steam Engine Works, Brooklyn, N. Y., died at his home in that city, April 1, aged 61 years.

Peter H. O. Willebrands, Vice-President of the Willebrands Machinery Co., of Detroit, Mich., died at his home in that city, March 29, aged 81 years.

John Davidson Peck, formerly Superintendent of the Brooklyn Wharf & Warehouse Co., died at his home in Brooklyn, N. Y., April 3, aged 78 years.

Richard Croker, Supervising Engineer in the Department of Buildings, New York City, died April 6, at Bloomfield, N. J., of paralysis, aged 38 years.

Theodore D. Buhl, President of the Buhl Malleable Iron Works, of Detroit, Mich., dropped dead in New York City, April 7, of apoplexy, aged 63 years.

Thomas Palmer, formerly Superintendent and Manager of the Cleveland Rolling Mill Co., of Cleveland, Ohio, died in that city, March 16. He was born in England, but came to America in 1855.

Edward J. Yard, Chief Engineer of the Denver & Rio Grande Ry., died at Denver, Colo., March 23, aged 47 years. He was born at Galveston, Texas, and entered the railway service in 1880 as Topographer of the Denver & Rio Grande Ry. For a few months in 1882 he was connected with the Texas, Santa Fe & Northern Ry., but in November of that year he reentered the employ of the former road. Since then he had been connected with that system, holding successively the positions of Engineer, Resident Engineer and Chief Engineer. He was appointed to the latter position Feb. 1, 1902.

ENGINEERING SOCIETIES.

COMING MEETINGS.

IOWA ELECTRICAL ASSOCIATION.
April 18-19. Annual Meeting at Clinton, Iowa. Secy., L. P. Spinney, Iowa State College, Ames, Iowa.

THE AMERICAN RAILWAY ASSOCIATION.
April 24. Annual Meeting at Chicago. Secy., W. F. Allen, 24 Park Pl., New York City.

AMERICAN ELECTROCHEMICAL SOCIETY.
May 2-4. Annual meeting at Philadelphia, Pa. Secy., S. S. Sadtler, 39 South 10th St., Philadelphia, Pa.

AMERICAN FOUNDRYMEN'S ASSOCIATION.
May 21-24. Annual convention at Philadelphia, Pa. Secy., Richard Moldenke, Watchung, N. J.

NATIONAL FIRE PROTECTION ASSOCIATION.
May 22-24. Annual Meeting at New York City. Secy., W. H. Merrill, 382 Ohio St., Chicago, Ill.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
May 28-31. Semi-annual Meeting at Indianapolis, Ind. Secy., Mr. Calvin W. Rice, Engineering Societies Bldg., 33 West 39th St., New York City.

NATIONAL ELECTRIC LIGHT ASSOCIATION.
June 4 to 7. Annual convention at Washington, D. C. Secy., W. C. L. Eglin, 29 West 39th st., New York City.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 12-14. Annual meeting at Atlantic City, N. J. Secy., J. W. Taylor, 390 Old Colony Bldg., Chicago, Ill.

MASTER CAR BUILDERS' ASSOCIATION.
June 17-19. Annual meeting at Atlantic City, N. J. Secy., J. W. Taylor, 390 Old Colony Bldg., Chicago, Ill.

AMERICAN WATER-WORKS ASSOCIATION.
June 17-22. Annual convention at Toronto, Ont. Secy., J. M. Diven, 14 George St., Charleston, S. C.

ASSOCIATION OF RAILWAY TELEGRAPH SUPERINTENDENTS.
June 19-20. Annual meeting at Atlantic City, N. J. Secy., P. W. Drew, Wisconsin Central Ry., Milwaukee, Wis.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 20-22. Annual meeting at Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia, Pa.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Annual convention at the City of Mexico, Mexico, between June 20 and July 20; exact date will be announced later. Secy., Charles Warren Hunt, 220 West 57th St., New York City.

ASSOCIATION OF TRANSPORTATION AND CAR ACCOUNTING OFFICERS.
June 25, 26. Annual meeting at St. Paul, Minn. Secy., G. P. Conard, 24 Park Place, New York, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 25-28. Annual convention at Niagara Falls, N. Y. Secy., Ralph W. Pope, 29 West 39th St., New York City.

SOCIETY OF CHEMICAL INDUSTRY.—A meeting of the New York section will be held April 19, at the Chemists' Club, 108 West 55th St., New York City. The program will be a symposium on soap, Messrs. J. Lewkowitsch, W. C. Alpers, Frank L. Randel, D. Wesson, Martin H. Ittner, J. Merritt Matthews, J. F. Hinckley, Wm. Dreyfus, A. C. Langmuir and N. J. Lane giving short discussions on its manufacture, use and composition.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS held its regular business meeting at its house on April 3, 1907; Mr. A. L. Bowman in the chair. Mr. C. C. Schneider, Past President of the Society, read abstracts from his paper on "Movable Bridges," which contains the first full set of specifications for movable bridges as a distinct and separate branch of the science of bridge design and construction. The paper aroused considerable interest and written discussions from Messrs. A. H. Smith, J. R. Worcester, C. R. Dart, and others were read.

WESTERN SOCIETY OF ENGINEERS.—At the meeting held at the society's rooms in Chicago on April 3, there was presented a paper by Mr. R. M. Hosea on "A Colorado Mountain Reservoir." The Sugar-Loaf reservoir is about five miles from Leadville, and is the property of the Colorado Fuel & Iron Co. The dam is of earth and clay, and as the presence of boulders in the borrow-pits made grading machines unsatisfactory, a small steam shovel was used, with dump cars. All filling around the outlet pipe and cross walls was done with the best clay available, put in by hand, tamped and puddled with water. The dam is 208 ft. wide at the base and 25 ft. on top, with three 48-in. pipes laid in a concrete bed or cradle, with concrete cross walls carried around and above the pipe at intervals. The pipes discharge into a concrete basin; their upstream ends are in a concrete inlet chamber, each pipe having a double-seated valve working vertically. An ample spillway is provided, capable of safely carrying off all flood discharge. The shrinkage of the material in the dam was 5.4%. The work was done by Clough & Anderson, of Colorado Springs, under the direction of Mr. Hosea as Chief Engineer, and the cost was slightly within the estimated amount of $127,655.

NEW YORK ACADEMY OF MEDICINE.—A meeting of the Public Health Section, held on April 4, was devoted to "The Street Cleaning Problem in New York City." The session was opened by a paper on "Street Dirt and Disease," by Dr. W. Gilman Thompson. Dr. Thompson, and also other physicians who spoke during the evening, were of the opinion that dirty streets and dusty air resulting therefrom affect the health of the people more through being predisposing causes to colds, pneumonia, and the like, than through any specific infection. Muddy and slushy streets and the attendant aerial dampness have very injurious effects upon invalids and non-robust persons generally; while dusty air does great harm through irritation of the whole respiratory tract. Captain F. M. Gibson, late Deputy Commissioner of Street Cleaning, outlined many of the "practical difficulties in cleaning the streets." Among these, push-carts and politics play a great part. Stress was also laid upon the manner in which the Street Cleaning Department had been hampered of late through the curtailment of the use of water for washing the streets. In a paper entitled "Practical Ideals of Street Cleaning," Mr. Rudolph Hering, M. Am. Soc. C. E., set forth in plain terms both the character of the problem and the best means of solving it, drawing largely upon European experience. A number of others took part in the discussion, including Dr. George A. Soper, M. Am. Soc. C. E., and Mr. M. N. Baker, of the editorial staff of this journal.

DEDICATION OF THE ENGINEERING SOCIETIES' BUILDING, NEW YORK CITY.—The program announced for the dedication exercises to be held on April 16-19 is as follows:

Tuesday, April 16, 3 p. m., Dedication Exercises; Presiding Officer, Charles Wallace Hunt.

1. Presentation of the gavel by Mrs. Andrew Carnegie.
2. Prayer by Rev. Edward Everett Hale, D. D., Chaplain U. S. Senate.
3. Communications from the President of the United States, the President of the Republic of Mexico, and the Governor-General of Canada.
4. Historical address by Mr. Charles F. Scott, Past-President American Institute Electrical Engineers, Chairman of the Conference and Building Committee.
5. Acceptance of the building by Mr. E. E. Olcott, President of the United Engineering Society.
6. Address by Mr. Andrew Carnegie.
7. Oration, Dr. Arthur Twining Hadley, President of Yale University, "The Professional Ideals of the Twentieth Century."

Tuesday evening, reception from 9 to 10.30 p. m., in the main Auditorium.

The receiving party will include the Presidents of the three Founder Societies and of the United Engineering Society, with their wives.

At 10.30 p. m., in the rooms of the Societies, the Officers and Councils of the Societies will receive the members and guests in the rooms of the respective Societies.

Supper will be served from 10 to 12 p. m., and the entire building will be on view.

Wednesday afternoon, April 17, 3 p. m., Founders' Day; Presiding Officer, John W. Lieb, Jr.

1. Address by the President of the American Institute of Electrical Engineers, Dr. Samuel Sheldon.
2. Address by the President of the American Society of Mechanical Engineers, Dr. Frederick Remson Hutton.
3. Address by the President of the American Institute of Mining Engineers, Dr. John Hays Hammond.
4. Presentation of Medals for Distinguished Services to Ralph W. Pope, Secy. Am. Inst. E. E.; Frederick R. Hutton, Past Secy. Am. Soc. M. E; Rossiter W Raymond, Secy. Am. Inst. M. E. By A. R. Ledoux, Past-President, United Engineering Society.
5. Presentation to the American Society of Mechanical Engineers of a portrait of George H. Corliss.
6. Presentation of John Fritz Gold Medal to Alexander Graham Bell, by Charles S. Scott, Chairman John Fritz Medal Board of Award.
7. Oration—"Ethics of Secret Processes in the Arts," by Dr. James Douglas, Past-President of the American Institute of Mining Engineers.

Professional Sessions of Founder Societies.

Thursday afternoon, April 18, 2 p. m.—Session of the American Institute of Mining Engineers.

A paper on "Mining Engineering in New York City," describing the excavation and tunnel work now being carried on by the Transportation Companies, will be read by Mr. H. T. Hildage.

Thursday evening, April 18, 8.15 p. m.—Session of the American Society of Mechanical Engineers.

An address on "The Ordnance Department as an Engineering Organization" will be delivered by Brigadier General William Crozier, Chief of Ordnance, U. S. Army.

Friday afternoon, April 19, 2 p. m.—Session of the American Institute of Mining Engineers.

Several professional papers on Metallurgy, Methods of Mining, Gas Engine Practice, the Treatment of Copper Ores, and various other subjects, will be read and discussed at this and the Thursday afternoon session.

Friday evening, April 19, 8 p. m.—An informal smoker and vaudeville for members of the Founder Societies will be held in Madison Square Garden.